STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

July 1975

AN ASSESSMENT OF ECONOMIC BENEFITS OF FIRESCOPE BASED ON HISTORICAL FIRES

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Prepared for:

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
BERKELEY, CALIFORNIA

PSW Grant No. 16

SRI Project MSU-3332

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ACKNOWLEDGEMENT

This report gives an economic analysis of alternative levels of capability for the FIRESCOPE (Fire Fighting Resources of Southern California Organized for Potential Emergencies) system. The need for a comprehensive analysis of benefits to be compared with costs was conceived by Stanley N. Hirsch, director of the FIRESCOPE program. As project monitor, Mr. Hirsch played a critical role in identifying the important issues for analysis and provided careful review of our findings and analytical methods throughout the project.

We would also like to thank the many individuals from the various FIRESCOPE agencies who provided information and critical review on our work. In particular we would like to thank Jerry Berry, Richard Chase, Ray Dalen, Gene Kemble, Myron Lee, Richard Montague, and Gene Murphy (U.S. Forest Service); Carl Downs, Joseph Springer, and Earl Young (California Division of Forestry); Ben Matthews, Robert Sarno, and Paul Snyder (Los Angeles County Fire Department); and Donald Ellis (Ventura County Fire Department). Of course, responsibility for the contents of the report rests with the authors rather than any of the individuals or organizations listed above.

I SUMMARY

The FIRESCOPE program (Fire Fighting Resources of Southern California Organized for Potential Emergencies) was established in 1972 to improve wildfire fighting efforts in Southern California. The program was to provide a number of functions, including communication and coordination, resource inventory control, infrared monitoring, and fire perimeter modeling. A variety of configurations was possible for the system, and so it was recognized at the outset of the design effort that an economic analysis of alternatives should be undertaken to ensure that the project was following the proper course.

In support of the design effort, SRI carried out a preliminary analysis of alternatives in late 1973. Three basic alternatives were considered, ranging from a system with no new hardware to a computer-aided system that was capable of coordinating several fires at one time. Direct assessments were obtained from FIRESCOPE personnel on the extent to which fire losses and costs might be reduced under each alternative. From the standpoint of reducing cost plus loss, the analysis showed that the most attractive alternative was the one based on the most sophisticated hardware, but the results were sensitive to changes in the experts' judgment. Therefore, the FIRESCOPE program manager decided to sponsor a more detailed analysis of the possible FIRESCOPE savings.

This report gives an economic analysis of seven FIRESCOPE alternatives. The analysis, which is based on historical fires, focuses on identifying the extent to which fire losses and suppression costs might be reduced under various FIRESCOPE options and gives particular attention to the role of accuracy in fire perimeter modeling. Perimeter modeling was judged to be of particular concern because of its potential high cost and because of existing uncertainty over how perimeter information affects suppression planning.

Working with the incident commanders and other senior officers who had served on the fires, we examined 16 fires in considerable detail to assess the savings that might have occurred if the various FIRESCOPE functions had been available during the fires. We also undertook a broader survey of 86 fires to serve as a check on the total maximum savings achievable under FIRESCOPE. The estimated savings were based on the best judgment that the officers could bring to bear on the fires several years after

the fires occurred. Although none of the officers had direct field experience with FIRESCOPE, many of them had been involved in the conceptual development of the program. Their experience and understanding of fire behavior and suppression needs was the best source of information available to us on the extent to which FIRESCOPE might reduce fire losses and suppression costs.

The analysis resulted in two principal findings:

- Savings of up to 25 percent in cost plus loss might be achieved under FIRESCOPE.

- Accuracy on time of arrival is not the important concern in fire perimeter modeling; the important concern is to identify the principal areas that might be reached by the fire.

Although detailed program implementation costs were not available for our analysis, it was calculated that, at present rates of fire incidence, a 1-percent reduction in cost plus loss would result in discounted savings of $3.25 million over 15 years at 10-percent interest. This rate of savings led to two important implications:

- The FIRESCOPE system appears economically justifiable at an estimated cost of $20 million.

- A relatively simple computerized model appears sufficient at this time for the purpose of perimeter prediction. Compared to a manual system, a simple computerized prediction capability might give additional discounted savings of $12 million extrapolated to all of Southern California experience. Increasing the level of accuracy might increase the discounted savings of the computerized prediction system by an additional $3 million.

The analysis showed that approximately 75 percent of the maximum possible savings would be the result of introducing common terminology, training procedures, and organizational standards, and improving communication and coordination. Approximately 20 percent of the potential savings would be the result of fire-perimeter and rate-of-spread information, and about 5 percent would be the result of information on spotting potential and flame conditions, such as intensity, height, and width. However, some of the communication and coordination savings probably would occur under today's 1975 technology and should not be attributed to the envisioned FIRESCOPE system. Thus the maximum possible FIRESCOPE savings may not be as great as indicated, and the relative contribution of perimeter modeling may be more than 20 percent.

In reviewing the fires, it was apparent that most of them would have burned until either the wind died down or the fuel was exhausted. The important need in minimizing the damages was to identify the principal areas where the fire was headed and to have good communication and coordination and a well-functioning organization. In many cases, it was nominally judged that a manual prediction system would have been sufficient to identify the principal areas that might have been threatened by the fire.

Information on time of fire arrival was of secondary importance. If the incident commander was aware of a threat and an action could be taken, there was usually sufficient time before the fire arrived that an incorrect prediction on time of arrival would not have adversely affected his suppression plans.

Sensitivity studies were conducted to determine how sensitive our results were to changes in judgment on the possible FIRESCOPE savings. The Coyote fire was found to be a critical factor in assessing the benefits of FIRESCOPE. Elimination of the Coyote fire savings from the analysis would have reduced the maximum potential savings in cost plus loss from about 25 percent to about 15 percent, but the absolute value of the savings due to a computerized prediction capability would have remained at the nominal level of $12 million. Shifting the Coyote fire savings that were nominally attributed to improved communication and coordination to a computerized prediction capability would have increased the present value of the computerized prediction system savings to about $40 million.

We limited our analysis to suppression planning on conflagration fires. However, the FIRESCOPE system might potentially be used for other purposes, such as initial attack planning on small fires; assisting in prescribed burning programs; and coordinating mutual aid efforts in non-fire disasters. It may be that a sophisticated computer facility would greatly enhance the economic benefit of these uses, but we did not examine these applications as they were beyond the scope of this analysis.

II INTRODUCTION

Wildfire-related losses and costs in Southern California are estimated to have averaged over $40 million per year during the last 20 years.[1] Approximately half the losses were the result of watershed damage; one quarter were the result of housing losses; and the remainder were the result of suppression costs; damage to recreation areas, aesthetics, and wildlife; loss of human life; and disruption of normal business patterns.

In a major effort to reduce these losses, Congress initiated the FIRESCOPE program in 1972. The program was motivated by the severe fire losses ($230 million) of the 1970 fire season. Foremost among the objectives of the FIRESCOPE program was the desire to provide an effective communication and coordination system for the many fire suppression agencies in Southern California. The program was to establish an agreed-upon incident command structure as well as common terminology, training, procedures, and organizational standards for all participating agencies. Supporting technologies and hardware capabilities were also to be developed to provide the incident commander with up-to-date reports of the fire behavior and suppression effort, including predictions on future fire spread.

The FIRESCOPE program is still in the research and development stage, but when fully implemented, the program will have consumed between $10 and $20 million in design and hardware acquisition. It was recognized early in the life of the program that there were many design options costing differing amounts and resulting in different levels of savings, and that an economic evaluation of alternatives should be made to help guide the design effort. Toward that end, SRI carried out a preliminary analysis of alternatives in late 1973.[1] That effort focused on three basic design alternatives, ranging from a system with no new hardware and only improved coordination procedures to a computer-aided system that was capable of monitoring up to 10 fires at one time and giving fire spread predictions for up to six hours in advance.

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[1] D. W. North, F. L. Offensend, and C. N. Smart, "An Economic Evaluation of Multi-Agency Communication and Coordination Systems for Southern California: A Preliminary Assessment," Stanford Research Institute, Menlo Park, California (February 1974).

The preliminary analysis drew heavily on the results of a workshop in which FIRESCOPE personnel were asked to give direct assessments on the extent to which fire losses and costs could be reduced under each of the alternatives. Those savings were then compared with the cost of each alternative and, from the standpoint of reducing total expected cost plus loss, the analysis showed that any one of the FIRESCOPE alternatives was more attractive than the present system of fire protection. The most attractive alternative was the one based on the most sophisticated hardware.

Sensitivity studies were conducted to determine the most critical inputs to the analysis. The analysis showed that the reduction factors assessed at the workshop were the most critical parameters and that if they were reduced to less than 25 percent of their assessed values, the most attractive alternative would shift to a system with less sophisticated hardware. The estimated savings were strictly preliminary and many of the workshop participants felt that an actual value of 25 percent of the assessed nominal value was entirely possible. It was therefore decided to have SRI carry out a more refined assessment of the various FIRESCOPE capabilities before finalizing the basic functions of the FIRESCOPE system.

The FIRESCOPE system is envisioned to have a number of possible functions, including communication and coordination, resource inventory control, fire behavior modeling, and infrared monitoring. Of particular concern to the FIRESCOPE program manager was the role of fire modeling. Fire modeling can take several forms, ranging from sets of predetermined tables, or prediction wheels, that give rough estimates on rate of spread, to sophisticated computer models that give detailed calculations on rate of spread and, therefore, fire perimeter over time. Other aspects of fire behavior could also be modeled, but the FIRESCOPE program manager was particularly concerned about perimeter predictions because it was felt that major resource allocation decisions are heavily based on where the fire is expected to be at future times.

Depending on the level of perimeter modeling capability provided, significant commitments could be required in weather prediction, fuels inventory, terrain mapping, software capabilities, and display devices. In order for FIRESCOPE management to decide what level of perimeter modeling capability to provide, it must know the expected level of savings in fire losses and suppression costs that would occur under each capability.

This report presents a more refined assessment of the FIRESCOPE system. Seven alternative systems are examined. The analysis depends on expert assessment and uses historical fires as a point of reference to establish the necessary input data. The model structure and information developed allow for a systematic evaluation of alternatives, including an analysis of the importance of accuracy in fire perimeter modeling.

III OBJECTIVES AND SCOPE

The objectives of the project were to:

- Refine the assessment methodology developed in SRI's first FIRESCOPE project (1973).
- Apply the methodology to a small but well-defined set of FIRESCOPE design alternatives.
- Assess the importance of accuracy in fire perimeter modeling.

It was recognized at the start of the project that information was still changing with respect to the design options and operating characteristics of the FIRESCOPE system. Thus, the analysis was to identify the most attractive alternatives, given present levels of information. Necessary input data for the study were to be provided by fire experts from the various agencies participating in the FIRESCOPE program.

Of primary interest to the FIRESCOPE program manager at the time the project was initiated was the issue of accuracy in fire perimeter modeling. It was assumed that increasing levels of accuracy would lead to improved decision making, but it was also recognized that those benefits would be achieved only at increased cost. The important issue to be resolved was determining the most cost-effective level of perimeter modeling, taking into account the costs of providing the prediction and the resultant savings in fire losses and suppression costs.

It was recognized that there were other issues to fire behavior besides perimeter modeling. But it was felt by the FIRESCOPE program manager that the primary emphasis of the study should be on perimeter modeling, because the strategic decisions of resource allocation and movement are usually set in response to where the fire is expected to be at future times. Detailed information on fire behavior conditions is of value to the incident commander, but for more tactical purposes. Hence, it was felt that the major emphasis of the study should be on perimeter prediction and not on flame conditions, such as intensity, height, and width. The analysis was to focus on suppression planning after the fire had escaped initial attack.

The issue of perimeter accuracy can be examined from many different perspectives, including hardware sophistication; software sophistication; or incident commander decision-making requirements. Ultimately, design

decisions have to be made concerning the hardware and software requirements but, before they can be made, the accuracy requirements for the perimeter prediction used by the incident commander in his decision making must be determined. Given a formal perimeter model, the effect of errors in input data on output predictions must also be determined.

This analysis will focus on the accuracy of the perimeter prediction used by the incident commander. It is expected that other contract work will determine the sensitivity relationships between input errors to the formal perimeter model and output errors on perimeter prediction, given a model of specified sophistication. Together the two analyses will provide a valuable input for specifying the hardware and software requirements for the perimeter modeling function.

IV METHOD OF APPROACH

We will use the criterion of minimum expected cost plus loss to evaluate the various FIRESCOPE alternatives. Depending on the functions provided, each configuration of the FIRESCOPE system will require differing capital and operating expenditures and will result in differing losses. From an economic standpoint, the most attractive alternative is the one that results in the least total cost to society, taking into account all fire losses, suppression costs, and program implementation costs. To provide a consistent basis for comparison, the various elements of cost and loss will be assessed on an average annual basis, since they are unpredictable and occur at different times. Thus, the most attractive alternative is the one that results in the least expected (average) annual cost plus loss to society. The interested reader is referred to other references for a more comprehensive description of the cost-plus-loss criterion.[1,2,3,4]

Implementation of the cost-plus-loss methodology would be a relatively straightforward matter if the fire losses and costs were known. The problem is that none of the design options has yet been implemented and data is not available on the fire losses and costs that would actually occur under FIRESCOPE. To overcome this problem, we elected to analyze a number of historical fires in an attempt to ascertain the savings that might have occurred if different levels of information had been available to the incident commander at the time of the fire. The analyses were carried out in close collaboration with the incident commanders and other senior officials who worked on the fires.

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[1] Ibid.

[2] K. P. Davis, Forest Fire: Control and Use (McGraw-Hill Book Company, New York, New York, 1959).

[3] J. M. Harrison, D. W. North, and C. A. Stael von Holstein, "Decision Analysis of Wildland Fire Protection: A Pilot Study," Revised Draft of Final Report, SRI Project 1555, Stanford Research Institute, Menlo Park, California (February 1973).

[4] R. A. Howard, D. W. North, F. L. Offensend, and C. N. Smart, "Decision Analysis of Fire Protection Strategy for the Santa Monica Mountains: An Initial Assessment," Preliminary Report, SRI Project MSU-2275, Stanford Research Institute, Menlo Park, California (June 1973).

It was recognized that a number of biases might be introduced by using subjective inputs from the incident commanders who served on the fires. First of all, they would be judging a new philosophy of fire fighting from a relatively traditional viewpoint and might not be able to appreciate some of the capabilities of the envisioned FIRESCOPE system. None of them would have had direct experience in working with FIRESCOPE because, of course, the system was not yet operational. There would also be the natural tendency of individuals to say that they had done the best job possible and that there was no possible way that the fire losses could have been reduced.

In spite of these problems, we felt that the fire officers who participated in this study were the best available sources for estimating the savings that might have occurred on the fires in question. They were the individuals who led the suppression efforts and were the ones who were most familiar with the major problems on the fires. They knew the kinds of information that were available at the times of the fires and were the only ones in a position to authoritatively state how the major decisions would have changed if different levels of information or fire-fighting capabilities had been available to them.

We found that the incident commanders were quite willing to discuss how the losses might have been reduced. Indeed, there was only one fire in our detailed sample in which no potential savings were identified (Dry Gulch fire), and that assessment was given by so many persons that we are confident of its validity. Although none of the incident commanders had direct field experience with FIRESCOPE, most of them had been involved in at least parts of its conceptual development. Furthermore, the analysis was structured so that a detailed knowledge of FIRESCOPE was not necessary. Thus the analysis was not carried out in the spirit of "how could FIRESCOPE have reduced the losses?" but rather "how could additional information and capabilities have affected the fire losses and costs?" The incident commanders were quite aware of their information needs on the various fires and, given those requirements and the envisioned capabilities of FIRESCOPE, it was a relatively straightforward matter to determine whether a particular FIRESCOPE function would have had an impact.

To assist the fire officers to analyze the fires, we introduced the concept of a point of interest. A point of interest is an area where control measures can be taken (e.g., ridgetops or fuel breaks) or where high values are at stake (e.g., urban developments or watershed areas). Points of interest are important because suppression efforts are usually focused on them, and so once we had identified the major points of interest on a fire, we could develop a systematic summary of the major suppression efforts and possible savings on the fire. This structure also helped

to reduce some of the biases mentioned above because it required the officers to focus on specific incidents in the fire.

The analysis was carried out in two stages. In the first stage, 16 fires were examined in considerable detail to estimate the savings that might have occurred if the various FIRESCOPE functions had been available. The purpose of the analysis was to determine the kinds of situations where FIRESCOPE would be of assistance and to develop an assessment of the expected savings that might be achieved under the various FIRESCOPE functions. The 16 fires were selected by the FIRESCOPE Task Force as being good examples of the kinds of fires where FIRESCOPE might have had a measurable effect. Assessments for the analysis were supplied by the incident commanders and other senior officers who were on the fires. Whenever possible, we worked with at least two officers so as to obtain a diversity of perspectives and to help ensure that all the major details were correctly recalled.

In the second stage, a broad survey of as many wildfires as possible was undertaken to serve as a check on the results of the 16-fire survey. By necessity, the survey could not go into as much detail as the 16-fire survey, but it was intended to identify the functions that were needed on each fire and the maximum possible savings that could have been achieved under FIRESCOPE. The survey was completed by the same fire officers who had collaborated on the 16 fires, and ultimately covered 86 fires. As in our first analysis, we limited the assessment to fires of over 1,000 acres, since they are responsible for most of the cost plus loss from wildfire in Southern California.

A number of caveats should be remembered in interpreting the results of this report. First, the analysis relies heavily on expert judgment, which, as discussed above, is subject to certain biases. Nevertheless, we believe that this judgment is the best available source of information for assessing the possible benefits of FIRESCOPE. The incident commanders and other senior officers who collaborated on this report knew the kinds of information and capabilities that were needed on each fire and were the only ones who could determine how their decisions would have changed if different levels of information and capabilities had been available at the time of the fire.

Second, the analysis was carried out on historical fires only. Our assumption was that even though the size and characteristics of future fires may change because of the increasing urbanization of wildland areas and increasing levels of fuel management practice, the same general kinds of suppression problems will occur in the future as have occurred in the past. Our hope was that we selected a broad enough range of fires to

cover the spectrum of problems encountered in major Southern California wildland fires.

Our analysis also assumed that each of the designated functions would be available and functioning correctly if it was part of the FIRESCOPE alternative in question. We did not allow for shutdowns due to personnel error, equipment breakdown, or preventive maintenance. We assumed that perimeter predictions could be made over any required time span; our only constraint was the accuracy of the prediction.

Our analysis focused on the decisions that would have been changed if different information had been available at the time of the fire. We did not concentrate on the decisions that would not have been changed and we did not investigate whether those decisions would have been adversely affected by erroneous FIRESCOPE information. Nor did we investigate the information requirements for the decisions that were made on the fire that were suppressed at less than 1,000 acres.

V ALTERNATIVE FIRESCOPE SYSTEMS

The possible configurations of the FIRESCOPE system are best described in terms of the functions provided by the system. Some of the basic functions that might be provided by FIRESCOPE are described below. Although the functions are described separately, it should be noted that possible synergisms are obtained through the combination of several functions.

A. Common Training, Terminology, Procedures, and Organizational Standards

There are dozens of fire agencies in Southern California, most having their own procedures and organizational standards. This has caused significant problems in interagency coordination during multiagency fire situations because the agencies simply have different operational standards. The purpose of this FIRESCOPE function is to provide common procedures and standards, as well as a unified command structure, so as to minimize interagency problems during multiagency incidents.

B. Improved Communication and Coordination

A significant problem in any major suppression effort is communicating directives and information on the current status of the fire to and from the incident commander. Without this information, it is impossible to effectively coordinate the suppression effort. The purpose of this function is to provide additional facilities, such as common radio channels, maps, display devices, and mobile vans so as to improve the communication and coordination between the incident commander and the officers on the line.

C. Computerized Resource Inventory

Regional Resources--The regional resource inventory function will provide the location, by agency and status, of all fire-fighting resources available for interagency use in Southern California. It will assist in the assignment of resources and help reduce the delay in obtaining resources for particular fires. It will also provide the incident commander with information on whether resources will be assigned to him, when they will arrive, and from where they will come.

On-Site Resources--The on-site resource inventory function will provide current status reports on the resources assigned to the fire, tell where they are located, and indicate their function. The information will be used to manage the current suppression effort and to help in responding to new tactical situations.

D. Perimeter Modeling

The fire perimeter prediction capability will be used to predict when the fire will reach a specified point of interest. As defined earlier, a point of interest is an area where control measures can be taken, such as at ridgetops or fuel breaks. Several levels of perimeter modeling capability are possible. For the purpose of characterizing basic alternatives, we will define the following capabilities.

Infrared Telemetering System--Under this capability, infrared information on the current position of the fire would be telemetered at frequent intervals to the incident commander. Predictions on fire spread would be based on this information as well as on local weather conditions and the use of tabularized data (as for example, the prediction wheel used by the U.S. Forest Service).

Computerized Prediction System ($\alpha = 1/2$)--A computerized model based on weather predictions, fuels, and terrain information will be used to provide an analytical prediction on fire spread. This prediction will then be adjusted by the incident commander to reflect his prior judgment on the fire's spread. A number of levels of accuracy are possible depending on the detail of the input data and software development provided. We will introduce the notation "α" to characterize the level of accuracy, where α gives the range relative to the true value in which the prediction will nearly always fall. For this analysis, we will assume that the incident commander's predicted time of arrival of the fire will fall in the specified interval 95 percent of the time. We will also assume that the predicted time of arrival will be normally distributed, with mean equal to the actual arrival time and standard deviation equal to one-fourth of the stated range.* Thus, an $\alpha = 1/2$ prediction system will give

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*Since 95 percent of the probability in a normal distribution is within $\pm$ 2 standard deviations of the mean, we will ensure that the predicted time of arrival falls in the stated α range 95 percent of the time by setting the standard deviation equal to one-fourth of the α range.

a prediction to within 50 percent of the correct value 95 percent of the time. For example, 95 percent of the time it will be accurate to within:

- ±3 hours if the actual time is 6 hours
- ±6 hours if the actual time is 12 hours
- ±18 hours if the actual time is 36 hours.

Computerized Prediction System (α = 1/3)--This computerized prediction system will give the prediction to within one-third of the correct value. Thus, for example, predictions on the time for the fire to arrive at a point of interest will be accurate 95 percent of the time to within:

- ±2 hours if the actual time is 6 hours
- ±4 hours if the actual time is 12 hours
- ±12 hours if the actual time is 36 hours.

Computerized Prediction System (α = 1/6)--This computerized prediction system will give the prediction to within one-sixth of the correct value. Thus, for example, the prediction on the time for the fire to arrive at a point of interest will be accurate 95 percent of the time to within:

- ±1 hour if the actual time is 6 hours
- ±2 hours if the actual time is 12 hours
- ±6 hours if the actual time is 36 hours.

Perfect Information on Fire Behavior Conditions after Escape--This level of fire modeling is provided as a theoretical upper bound on the capabilities of fire modeling. Under this capability, the incident commander would be provided with perfect information on the spread of the fire after escape, as well as perfect information on the detailed behavioral characteristics of the fire, including such factors as spotting, intensity, flame height, flame width, and breaks in the fire weather. It should be pointed out that this alternative could probably never be achieved in practice.

E. Alternative Systems Designs

A large number of FIRESCOPE configurations could be generated based on all combinations of the above functions. For simplicity, we have selected seven alternatives as being representative. Reflecting the interest of the FIRESCOPE program manager, the alternatives have been selected so that the principal difference between them is the level of fire perimeter modeling provided. The seven options are listed in Table 1.

Table 1

ALTERNATIVE FIRESCOPE SYSTEMS

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing fire protection system at the time of the fire	Common training, terminology, procedures, and organizational standards	Common training, terminology, procedures, and organizational standards	Common training, terminology, procedures, and organizational standards	Common training, terminology, procedures, and organizational standards	Common training, terminology, procedures, and organizational standards	Common training, terminology, procedures, and organizational standards
	Improved communication and coordination	Improved communication and coordination	Improved communication and coordination	Improved communication and coordination	Improved communication and coordination	Improved communication and coordination
	Computerized resource inventory	Computerized resource inventory	Computerized resource inventory	Computerized resource inventory	Computerized resource inventory	Computerized resource inventory
	Perimeter modeling:	Perimeter modeling:	Perimeter modeling:	Perimeter modeling:	Perimeter Modeling:	Perimeter modeling:
	• Prediction wheel	• Infrared telemetering	• Infrared telemetering	• Infrared telemetering	• Infrared telemetering	• Infrared telemetering
		• Prediction wheel	• Computerized prediction system ($\alpha = 1/2$)	• Computerized prediction system ($\alpha = 1/3$)	• Computerized prediction system ($\alpha = 1/6$)	• Perfect information on fire behavior conditions after escape (perhaps not achievable in practice)

VI PRINCIPAL RESULTS

The results of our FIRESCOPE analysis fall into two categories: those based on a detailed analysis of 16 fires, and those based on a broader survey of 86 fires. This chapter summarizes the principal results of our analysis and gives some additional results on the maximum amount that could be justifiably spent on each alternative. Detailed narratives for the individual fires are given in Appendix A.

A. Analysis of 16 Historical Fires

The first phase of our analysis was directed toward carrying out a detailed examination of 16 fires in an attempt to ascertain the savings that might have occurred if the various FIRESCOPE functions had been available at the time of the fires. The estimated savings were developed in close collaboration with the incident commanders and other senior officers who were on the fires. It should be pointed out that several of the fires occurred a number of years ago and it was sometimes impossible to recall the exact fire situation and sequence of events. Even if all the details were correctly recalled, it was not always possible to accurately determine how the losses would have changed if different decisions had been made at the time of the fires.

For these reasons, the results that follow should be interpreted as being based on the best judgment that the incident commanders can make today. Sensitivity studies are reported in Chapter VII and Appendix B showing how the results of our analysis would change for specified changes in judgment on the individual fires.

Table 2 lists the fires and fire officers who collaborated on each of the 16 fires.

Table 2

LIST OF 16 FIRES SURVEYED

Name	Jurisdiction	Acres Burned	Houses Lost	Suppression Cost (1970 dollars)	Officials Consulted
Potrero (1973)	Ventura County	12,800	0	240,000	Donald Ellis
Romero (1971)	Los Padres	14,538	4	1,800,000	Jerry Berry Ray Dalen
Bear (1972)	Los Padres	17,150	0	2,200,000	Jerry Berry Ray Dalen
Coyote (1964)	Los Padres	67,000	110	4,600,000	Jerry Berry Ray Dalen Carl Hickerson
Wellman (1966)	Los Padres	93,600	0	3,455,000	Jerry Berry Ray Dalen
Buckeye (1970)	Los Padres	44,000	15	500,000	Jerry Berry Ray Dalen
Soboba (1974)	San Bernardino	17,683	0	1,640,000	Gene Kemble Gene Murphy Robert Irwin Earl Young Joe Springer
Bear (1970)	San Bernardino	53,100	10	1,800,000	Gene Kemble
Rolling Hills (1973)	LA County	897	12	125,000	Paul Snyder Robert Sarno
Dry Gulch (1974)	LA County	5,800	0	170,750	Paul Snyder Robert Sarno Richard Montague
Wright (1970)	LA County	27,925	103	1,250,000	Ben Matthews Russ Stallings
Topanga (1973)	LA County	1,700	0	94,000	Ben Matthews
Laguna (1970)	Cleveland	175,420	382	1,500,000	Myron Lee
Boulder (1970)	Cleveland	12,900	5	1,500,000	Myron Lee
Stewart (1958)	Cleveland	68,300	14	1,878,000	Myron Lee
Paseo Grande (1967)	Orange County	48,639	67	2,944,750	Carl Downs

1. FIRESCOPE Capabilities Desired

Each fire was carefully reviewed with the fire officers to determine the major points of interest. For each point of interest, the officers were asked to identify the kinds of information that were available; the principal decisions that were made; how those decisions would have changed if different information had been available; and the savings that would have occurred if the decisions had been changed. If the estimated savings were the result of information that could have been provided by one of the FIRESCOPE functions, then those savings were assigned to the FIRESCOPE function providing that information. The functions so identified are listed in Table 3 for each of the 16 fires. A blank entry in the table means either that the function was not needed or that it was performed well enough that additional assistance from FIRESCOPE would have been of little additional value.

a. Situation Assessment

Table 3 shows that a wide variety of information sources had to be collected and coordinated for each fire. The required level of information varied with the fire, but, in general, there was an expressed need for a comprehensive summary of the current fire suppression effort, available resources, and projected fire perimeter. Much of this information would have been provided through improved communication and coordination as well as resource inventory control and fire perimeter modeling capabilities. Multiagency efforts would have also been enhanced by the introduction of common training, terminology, procedures, and organizational standards for all FIRESCOPE agencies. Many of the same information-gathering tasks that are performed today would still be performed under FIRESCOPE, but instead of being performed by the incident commander in a crisis mode, they would be carried out in a more planned manner by an individual who was properly located in the organization to carry out that function.

b. Fire Perimeter Modeling

In 13 of the 16 fires, there was an expressed need for information on the future behavior of the fire. However, as shown in Table 4, the type of information needed depended on the fire.

Table 3

DESIRED FIRESCOPE FUNCTIONS FOR 16 FIRES

Fire	Common Training, Terminology, Procedures, and Organizational Standards	Communication and Coordination	Regional Resource Inventory	On-Site Resource Inventory	Perimeter Modeling
Potrero		x		x	x
Romero	x	x		x	x
Bear-LP	x	x		x	x
Coyote	x	x	x	x	x
Wellman	x		x		x
Buckeye			x		x
Soboba	x	x		x	x
Bear-SB		x		x	x
Rolling Hills	x	x			x
Dry Gulch					
Wright	x	x			
Topanga	x				
Laguna			x	x	x
Boulder					x
Stewart	x				x
Paseo Grande	x	x	x	x	x

Table 4

FIRE MODELING CAPABILITIES NEEDED FOR 16 FIRES

Fire	Current Fire Location	Points of Interest That Might Be Threatened	Prediction on Time of Fire Arrival at Specified Point of Interest	Prediction of Detailed Fire Condition, Such as Intensity, Flame Height, and Flame Width
Potrero	x			
Romero				x
Bear-LP			x	x
Coyote		x	x	
Wellman		x	x	
Buckeye			x	
Soboba		x		
Bear-SB			x	
Rolling Hills		x	x	
Dry Gulch				
Wright				
Topanga		x		
Laguna	x		x	
Boulder		x		
Stewart		x		
Paseo Grande	x	x	x	

In some fires, such as the Stewart fire, the need was mostly for a system that would make the incident commander aware of the major points of interest. On that fire, one of the main problems in the suppression effort was not anticipating that the fire would turn back the first night and cross Ortega Highway. The weather shift that caused the fire to change direction was normal for the region and had occurred in another fire in the immediate area only weeks before. If the threat to the Ortega Highway had been realized sufficiently early in the course of the fire, there would have been time to establish a major secondary defensive effort at the highway. Such an effort would have saved up to 30,000 acres and 14 houses. The problem was not in predicting when the fire would reach the Ortega Highway, but rather of realizing that the highway might become a key defensive line in the suppression effort.

In other fires, such as the Paseo Grande fire, there was a marked need to determine when the fire would reach a particular point of interest. The Paseo Grande fire started at about 3:00 pm. At midnight it was recognized that several communities would be threatened the next day, but it was judged that the fire would not reach them until perhaps 9:00 or 10:00 am. In fact, the fire reached the housing areas between 4:00 and 5:00 am and 69 houses were destroyed. If the incident commander had known the fire was going to arrive earlier in the morning, he would have mobilized much faster and probably would have been able to save up to 70 percent of the houses.

On still other fires, the need was not so much to predict the rate of spread, but rather to predict the actual behavior of the flame conditions. This was particularly true in the Romero fire, where several fruitless efforts were made to contain the fire as it was spreading along the mountainside. Sophisticated fire behavior models that could have predicted the spotting potential, flare-ups, and flame intensity would have indicated the extreme difficulty of the suppression effort. If the incident commander had been provided with this information, he might have changed the overall strategy to either retreating to the final perimeter and firing out the entire area, or making a more concentrated effort at controlling the fire at an intermediate ridgetop. The former strategy would have reduced the suppression costs by about 10 to 20 percent, while the latter strategy might have given a 50-percent chance of saving half the burned acreage (or expected savings of 3,635 acres). In either case, the information would have reduced the expected cost plus loss of the fire.

2. Economic Impact of FIRESCOPE Alternatives

The importance of the functions listed in Tables 3 and 4 can be assessed in economic terms. In addition to identifying the kinds of FIRESCOPE capabilities needed, the incident commanders were also asked to estimate the savings in houses, acreage, and suppression costs that would have occurred if the desired functions had been present.

a. Classification of FIRESCOPE Savings

In most cases, it was a straightforward matter to assign the estimated savings to particular FIRESCOPE capabilities. For example, if the incident commander estimated that a 2,000-acre spillover could have been avoided by having real-time infrared photos of the fire, the indicated savings were assigned to the infrared function. But the assignment of savings was not so obvious in situations where the need was for a system

that would simply make the incident commander aware of all points of interest. In these difficult-to-classify situations, it was necessary to determine whether the training and organizational setup of FIRESCOPE would have been sufficient to ensure that all major points of interest would be considered by the command structure or whether a more formal regimen, such as provided by a computer, was needed.

The actual assessment of the necessary prediction system depended on the fire but, as shown in Appendix A, we determined in many cases that a formal computerized model was necessary to ensure that all points of interest would be considered by the command structure. The reason was not only that the data were too complicated for an individual to process or that a computer could have necessarily done a better job, but that the existence of a computerized prediction system would have documented the prediction and emphasized the need to consider the indicated points of interest. For example, field predictions were made on the Soboba fire in mid-afternoon, saying that the fire would reach the Banning-Idylwild Highway by early evening. However, the highway was never actively considered by the top command structure as a potential defensive line until late afternoon. By then, it was too late to take any action and 6,000 acres of valuable timberland were lost. If a computerized prediction had been made during the afternoon, it is likely that the threat to the Banning-Idylwild Highway would have been recognized and documented early enough to save much of the 6,000 acre spillover.

b. Cost-Plus-Loss Calculations

Table 5 summarizes the estimated savings that were identified in the 16-fire survey. As indicated earlier, the estimated savings should be viewed as being a reflection of the best judgment that the incident commanders could bring to bear on how the fire costs and losses might have been reduced if different information and capabilities had been available to them at the time of the fires. The fire narratives, assumptions, and calculations that led to the table are given in Appendix A. All cost and loss figures are expressed in 1970 dollars and are based on value assignments (for watershed and structural values) furnished by the incident commanders.

The results do not take into account the cost of developing, acquiring, or operating the FIRESCOPE alternatives. These costs must be considered when the final design selection decision is made.

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The results do not take into account the cost of developing, acquiring, or operating the FIRESCOPE alternatives. These costs must be considered when the final design selection decision is made.

Table 5

COST PLUS LOSS UNDER FIRESCOPE FOR 16 FIRES
(1970 Dollars)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Potrero	$ 3,248,000	$ 3,248,000	$ 2,738,000	$ 2,738,000	$ 2,738,000	$ 2,738,000	$ 2,738,000
Romero	8,315,400	8,194,800	8,194,800	7,858,800	7,822,800	7,794,800	5,966,750
Bear-LP	7,602,250	7,382,250	7,382,250	7,382,250	7,382,250	7,382,250	7,162,250
Coyote	49,021,000	19,482,795	19,482,795	19,147,925	19,147,925	16,876,725	16,876,725
Wellman	7,667,000	7,442,000	7,442,000	6,962,000	6,962,000	6,962,000	6,443,250
Buckeye	15,566,000	13,868,900	13,868,900	13,868,900	13,868,900	13,868,900	13,868,900
Soboba	8,448,000	7,669,000	7,669,000	3,672,000	3,672,000	3,672,000	3,642,000
Bear-SB	24,903,500	24,478,500	24,478,500	24,105,420	24,079,920	24,069,700	24,069,700
Rolling Hills	2,819,555	2,015,555	2,015,555	1,622,755	1,613,555	1,613,555	1,533,145
Dry Gulch	750,750	750,750	750,750	750,750	750,750	750,750	750,750
Wright	22,452,125	19,882,100	19,882,100	19,882,100	19,882,100	19,882,100	19,882,100
Topanga	519,000	439,000	439,000	439,000	439,000	439,000	429,600
Laguna	65,542,600	63,532,600	63,382,600	63,198,900	63,175,000	63,140,100	63,134,400
Boulder	6,089,500	6,089,500	6,089,500	5,639,500	5,639,500	5,639,500	5,639,500
Stewart	12,106,500	6,223,500	6,223,500	6,223,500	6,223,500	6,223,500	6,223,500
Paseo Grande	17,516,235	14,836,235	13,094,235	10,280,235	10,280,235	10,280,235	10,280,235
Total cost plus loss for 16 fires	$252,567,415	$205,535,485	$203,153,485	$193,772,035	$193,677,535	$191,333,115	$188,640,805
Percent reduction	--	18.62%	19.56%	23.27%	23.32%	24.24%	25.30%

c. Importance of Situation Assessment

Table 5 shows that significant savings in the cost plus loss for the 16 fires could have been achieved if the various FIRESCOPE functions had been available at the time of the fires. For the combinations of functions examined, the table shows that the cost plus loss for the 16 fires could have been reduced by 18.6 to 25.3 percent.

The table shows that almost three-fourths of the estimated maximum possible savings could have been achieved under Alternative 2. That alternative would have provided improved situation assessment through common training, terminology, procedures, and organizational standards; communication and coordination; and computerized resource inventory control. However, it would be misleading to assume that equivalent reductions would occur in future fires under the Alternative 2 functions. Most of the savings attributed to Alternative 2 were due to assumed improvements in communication and coordination and organizational structure. However, many of the 16 fires occurred several years ago, and since that time, a number of improvements have been made in Southern California's ability to organize and effectively carry out a major suppression effort. Thus, some of the savings indicated under Alternative 2 should probably be attributed to improvements in fire-fighting technology that have already occurred and not to the new innovations of FIRESCOPE. In Chapter VII on sensitivity analysis, an attempt will be made to identify the fraction of Alternative 2 savings that should be attributed to FIRESCOPE.

d. Importance of Fire Modeling

In a number of fires, a formal fire modeling capability would have added measurable benefits to the FIRESCOPE system. But, as shown in Table 5, the extent of the savings would have depended on the level of fire modeling capability provided. Thus, compared to a reduction in cost plus loss of 18.6 percent under Alternative 2, the reductions would have been 23.3 and 25.3 percent under Alternatives 4 and 7, respectively. Alternative 4 would provide a relatively crude ($\alpha = 1/2$) prediction on perimeter, and Alternative 7 assumed perfect information on all fire conditions after escape.

Perimeter Prediction Modeling--The most important observation on fire modeling to be drawn from Table 5 is that most of the fire modeling savings would have been achieved under a relatively crude level of perimeter modeling. The table lists the various fire modeling capabilities in ascending levels of accuracy and sophistication. A comparison

of the prediction alternatives shows that the greatest marginal benefit occurs in going from a FIRESCOPE system with no formal fire modeling capability to one with a relatively crude level of accuracy on the time for the fire to arrive at a point of interest ($\alpha = 1/2$).

The principal attribute of this relatively crude perimeter prediction model is that it identifies and documents the major points of interest that might be reached by the fire. Compared to what many fire officials claim they can do, it provides a relatively inaccurate prediction on the time for the fire to arrive at the point of interest. It can be off by as much as 50 percent on time of predicted fire arrival.

In spite of the rather large prediction error on time of arrival, significant improvements in cost plus loss can be made under this system as opposed to a system with no formal fire modeling capability. The reason is that the formal system would at least make the incident commander aware of all major points of interest. The major problem on many of the fires, such as the Soboba fire, was that the top command structure did not actively consider the threat to a major point of interest until it was too late to take any significant action. The problem was not so much of precisely determining when the fire would reach the point of interest, but rather of realizing that the point of interest would be threatened. It was judged that a crude level of perimeter prediction ($\alpha = 1/2$) would have provided this capability, and hence significant additional savings were assigned to Alternative 4.

A second observation to be drawn from Table 5 is that relatively few additional benefits are gained by adding successively more accurate levels of perimeter prediction capability. The reductions in cost plus loss would have been 23.3 percent under the $\alpha = 1/2$ capability and 24.2 percent under the $\alpha = 1/6$ capability. The two systems would predict the time of arrival within 50 percent and 15 percent of the correct time, respectively.

The reason that few additional savings are shown for the $\alpha = 1/6$ system is that few situations were encountered on the 16 fires in which major decisions would have been made differently if the time of arrival had been known more accurately than under a simpler prediction ($\alpha = 1/2$). For example, in the Paseo Grande fire, a prediction was made at midnight that the fire would reach the Lemon Heights area about 10 hours later. In fact, the fire arrived there in 4 hours. If an $\alpha = 1/2$ prediction system had been available, the predicted time of arrival would have been between 2 and 6 hours. The incident commander felt that a predicted arrival time of less than 6 hours (but more than 1 or 2) would have caused him to mobilize much faster than he actually did. Thus, he would

have made the same decision under an $\alpha = 1/2$ prediction as under an $\alpha = 1/6$ prediction. In either case, the earlier mobilization of forces would have allowed for saving up to 70 percent of the 69 houses destroyed.

The important issue in assessing the importance of accuracy is determining the effect that different levels of accuracy would have had on suppression decisions and ensuing losses. In very few instances did we find situations where an inaccurate prediction on rate of spread misled the incident commander to thinking that there was not enough time to defend a particular point of interest when, in fact, there was sufficient time. Nor did we find many situations where he would have attempted a different defensive strategy if he had known that the fire was traveling faster than predicted. It is likely that a highly sophisticated spread model would be required to predict the actual spread of a large fire like the Paseo Grande fire. But if those more exact predictions have little effect on the decisions, then from the standpoint of reducing fire losses and costs, the information has little value.

Fire Behavior Modeling--A third observation to be drawn from Table 5 is that perfect information on the fire conditions after escape would have increased the reductions in cost plus loss by only about 1 percent, from 24.2 percent to 25.3 percent. Because the analysis was primarily focused on the question of perimeter accuracy, we did not explicitly address our interview questions to detailed fire behavior considerations, such as flame intensity, flame height, and spotting potential. Nevertheless, in the course of the interviews, the incident commanders were asked what they would have done differently if they had had perfect predictions on all fire conditions after escape. The additional savings they indicated are shown in the last column of Table 5, and they represent the marginal savings that would have been achieved if perfect information had been available on fire behavior. It should be pointed out that perfect predictions could probably never be achieved in practice, but this alternative does provide an upper bound on the maximum possible savings of FIRESCOPE as well as the maximum marginal contribution of fire behavior information.

An examination of the fire histories shows that most of the savings from perfect information are the result of reductions in the suppression effort. For example, in the Romero fire, a number of fruitless efforts were made to contain the fire as it spread from ridgetop to ridgetop. The fire was lost at each of the ridgetops because of sudden flareups and intense flame conditions in areas where such conditions were not expected. If the exact fire behavior had been known, many of the ridge attacks would have been eliminated, saving up to 10 to 20 percent of the

suppression costs as well as eliminating an added risk to the safety of the men. Given this perfect information, there is also a possibility that the incident commander would have concentrated his attack on a later ridge, giving an expected savings of 3,625 acres of high value watershed.

It is important to note that even if perfect information had been available on all fire behavior conditions after escape, almost 80 percent of actual losses still would have occurred. Fire losses are not going to be completely eliminated under FIRESCOPE, even if it could provide perfect information on fire behavior. Most major fires burn until either the wind dies down or the fuel is exhausted and, during such extreme conditions, there is little that can be done to contain the fires.

3. The Impact of FIRESCOPE by Loss Category

It is instructive to examine the extent to which FIRESCOPE would have reduced the individual categories of fire losses and costs. As shown in Appendix A, data for the individual fires can be reorganized to determine the impact that FIRESCOPE would have had on the major categories of acreage-related losses, housing-related losses, and suppression costs. The reduction factors by loss category are then easily calculated and are given in Tables 6, 7, and 8. These tables are important because they show how the different FIRESCOPE capabilities would impact on the various categories of cost plus loss.

All three loss categories are significantly affected by the situation assessment functions of common training, terminology, procedures, and organizational standards; communication and coordination; and computerized resource inventory control. Suppression costs would be reduced by only 15.5 percent under these capabilities compared to reduction of 18.6 and 19.8 percent for acreage- and housing-related losses. The reason that suppression costs are not as significantly affected under improved situation assessment is that the same number of resources would usually be used even if there was improved communication and coordination. The only difference is that they would be deployed more effectively under improved situation assessment.

On the Topanga fire, for example, it was estimated that there would have been an 80-percent chance of saving 400 acres in the Tuna Canyon area because of improved procedural and organizational standards, but this effort would have taken just as many resources as were actually used in controlling that section of the fire.

Table 6

ACREAGE LOSSES UNDER FIRESCOPE FOR 16 FIRES
(1970 Dollars)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Potrero	$ 3,008,000	$ 3,008,000	$ 2,538,000	$ 2,538,000	$ 2,538,000	$ 2,538,000	$ 2,538,000
Pomero	6,033,000	6,033,000	6,033,000	6,033,000	6,033,000	6,033,000	4,524,950
Bear-LP	5,402,250	5,402,250	5,402,250	5,402,250	5,402,250	5,402,250	5,402,250
Coyote	31,155,000	11,021,660	11,021,660	10,729,875	10,729,875	10,729,875	10,729,875
Wellman	4,212,000	3,987,000	3,987,000	3,852,000	3,852,000	3,852,000	3,852,000
Buckeye	13,860,000	12,222,000	12,222,000	12,222,000	12,222,000	12,222,000	12,222,000
Soboba	6,808,000	6,193,000	6,193,000	2,360,000	2,360,000	2,360,000	2,360,000
Bear-SB	22,567,500	22,142,500	22,142,500	22,142,500	22,142,500	22,142,500	22,142,500
Rolling Hills	282,555	282,555	282,555	282,555	282,555	282,555	268,695
Dry Gulch	580,000	580,000	580,000	580,000	580,000	580,000	580,000
Wright	7,400,125	5,920,100	5,920,100	5,920,100	5,920,100	5,920,100	5,920,100
Topanga	425,000	345,000	345,000	345,000	345,000	345,000	345,000
Laguna	33,329,800	33,329,800	33,329,800	33,153,100	33,130,300	33,098,000	33,092,300
Boulder	4,321,500	4,321,500	4,321,500	4,321,500	4,321,500	4,321,500	4,321,500
Stewart	9,220,500	5,170,500	5,170,500	5,170,500	5,170,500	5,170,500	5,170,500
Paseo Grande	5,593,485	5,593,485	5,593,485	5,593,485	5,593,485	5,593,485	5,593,485
Total acreage-related losses for 16 fires	$154,198,715	$125,552,350	$125,102,350	$120,645,865	$120,623,065	$120,590,765	$119,063,155
Percent reduction	--	18.58%	18.87%	21.76%	21.77%	21.79%	22.78%

Table 7

HOUSING LOSSES UNDER FIRESCOPE FOR 16 FIRES
(1970 Dollars)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Potrero	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Romero	482,400	361,800	361,800	361,800	361,800	361,800	361,800
Bear-LP	0	0	0	0	0	0	0
Coyote	13,266,000	6,833,800	6,833,800	6,833,800	6,833,800	4,562,600	4,562,600
Wellman	0	0	0	0	0	0	0
Buckeye	1,206,000	1,206,000	1,206,000	1,206,000	1,206,000	1,206,000	1,206,000
Soboba	0	0	0	0	0	0	0
Bear-SB	536,000	536,000	536,000	144,720	117,920	107,200	107,200
Rolling Hills	2,412,000	1,608,000	1,608,000	1,215,200	1,206,000	1,206,000	1,145,700
Dry Gulch	0	0	0	0	0	0	0
Wright	13,802,000	12,462,000	12,462,000	12,462,000	12,462,000	12,462,000	12,462,000
Topanga	0	0	0	0	0	0	0
Laguna	30,712,800	28,702,800	28,702,800	28,702,800	28,702,800	28,702,800	28,702,800
Boulder	268,000	268,000	268,000	268,000	268,000	268,000	268,000
Stewart	1,008,000	0	0	0	0	0	0
Paseo Grande	8,978,000	6,298,000	4,556,000	1,742,000	1,742,000	1,742,000	1,742,000
Total housing-related losses for 16 fires	$72,671,200	$58,276,400	$56,534,400	$52,936,320	$52,900,320	$50,618,400	$50,558,100
Percent reduction	--	19.81%	22.20%	27.16%	27.21%	30.34%	30.43%

Table 8

SUPPRESSION COSTS UNDER FIRESCOPE FOR 16 FIRES

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Potrero	$ 240,000	$ 240,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000	$ 200,000
Romero	1,800,000	1,800,000	1,800,000	1,464,000	1,428,000	1,400,000	1,080,000
Bear-LP	2,200,000	1,980,000	1,980,000	1,980,000	1,980,000	1,980,000	1,760,000
Coyote	4,600,000	1,627,335	1,627,335	1,584,250	1,584,250	1,584,250	1,584,250
Wellman	3,455,000	3,455,000	3,455,000	3,110,000	3,110,000	3,110,000	2,591,250
Buckeye	500,000	440,900	440,900	440,900	440,900	440,900	440,900
Soboba	1,640,000	1,476,000	1,476,000	1,312,000	1,312,000	1,312,000	1,282,000
Bear-SB	1,800,000	1,800,000	1,800,000	1,818,200	1,819,500	1,820,000	1,820,000
Rolling Hills	125,000	125,000	125,000	125,000	125,000	125,000	118,750
Dry Gulch	170,750	170,750	170,750	170,750	170,750	170,750	170,750
Wright	1,250,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Topanga	94,000	94,000	94,000	94,000	94,000	94,000	84,600
Laguna	1,500,000	1,500,000	1,350,000	1,343,000	1,342,000	1,339,300	1,339,300
Boulder	1,500,000	1,500,000	1,500,000	1,050,000	1,050,000	1,050,000	1,050,000
Stewart	1,878,000	1,053,000	1,053,000	1,053,000	1,053,000	1,053,000	1,053,000
Paseo Grande	2,944,750	2,944,750	2,944,750	2,944,750	2,944,750	2,944,750	2,944,750
Total suppression costs for 16 fires	$25,697,500	$21,706,735	$21,516,735	$20,189,850	$20,154,150	$20,123,950	$19,019,550
Percent reduction	--	15.53%	16.27%	21.43%	21.57%	21.69%	25.99%

The addition of the infrared scanner would have made a measurable improvement in housing losses, increasing the reduction factor from 19.8 to 22.2 percent. These savings were mostly from the Paseo Grande fire. Lesser improvements were found for acreage-related losses and suppression costs.

The addition of a fire perimeter modeling function would have had a measurable effect on acreage-related losses, increasing the reduction factor for those losses from 18.9 to 21.8 percent. It is important to note, however, that the reduction factor for acreage-related losses would have remained essentially the same (21.8 percent) under all three levels of accuracy considered. As in the case of the Banning-Idylwild Highway on the Soboba fire, the important factor with respect to acreage-related losses was making the incident commander aware of all major points of interest, and not necessarily furnishing him with the exact time of arrival.

Reductions in acreage-related losses would have been further improved, from 21.8 percent to 22.8 percent, if perfect information on fire behavior conditions after escape had been available. These reductions would have occurred because the suppression effort in certain instances is highly dependent on advance information on detailed fire behavioral conditions. Thus, for example, in the Romero fire, the incident commander might have decided early in the fire to defend an intermediate ridgetop if perfect predictions on flame conditions and breaks in the fire weather had been available. Such a decision would have given an expected savings of 3,625 acres.

A simple ($\alpha = 1/2$) fire perimeter modeling function would have increased the reduction in housing-related losses from 22.2 to 27.5 percent. Only moderate improvements would have been achieved, however, by adding increasing levels of fire perimeter accuracy or by furnishing perfect information on fire behavior. The lack of significant additional improvement under more accurate levels of perimeter prediction is a reflection of the importance placed on minimizing urban damage. So long as the incident commander is aware of an urban threat and generally knows about when the fire will arrive there, he will try to defend that area if there is any reasonable chance of saving it. Thus, with respect to housing losses, the important need is to ensure that the incident commander is made aware of all urban threats. It is not as necessary under the present philosophy of handling urban threats to furnish him with the exact time of arrival or detailed information on fire behavior.

Suppression costs, on the other hand, are markedly influenced by the amount of information on fire conditions supplied. A relatively

crude perimeter modeling capability ($\alpha = 1/2$) would have increased the reduction in suppression costs from 16.3 to 21.4 percent. The reductions would have increased to 21.7 percent under a more accurate level of perimeter accuracy ($\alpha = 1/6$) and to 26.0 percent under perfect information on fire behavior conditions after escape.

The increase in suppression cost savings with increasing levels of fire behavior information shows how dependent suppression planning is on advanced information on fire conditions. Without accurate information, the suppression effort must be planned for the worst case, but with the information, the suppression force can be more closely fitted to the actual needs. The result for the 16 fires was an improvement in suppression costs savings, from 16.3 percent to as much as 26.0 percent.

It is important to put the three major components of cost plus loss in perspective. Table 9 gives the percentage contribution of the three components of total cost plus loss by FIRESCOPE design alternative.

Table 9

PERCENTAGE CONTRIBUTION TO TOTAL COST PLUS LOSS
BY COST AND LOSS CATEGORY FOR SEVEN FIRESCOPE ALTERNATIVES

	Alternative						
	1	2	3	4	5	6	7
Acreage losses	61.0%	61.1%	61.6%	62.3%	62.3%	63.0%	63.1%
Housing losses	28.7	28.3	27.8	27.3	27.3	26.5	26.8
Suppression costs	10.3	10.6	10.6	10.4	10.4	10.5	10.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

It shows that the percentage contribution by category is approximately invariant among the different alternatives. More important, it shows that suppression costs accounted for only about 10 percent of the total cost plus loss in the 16-fire sample. Thus, even though suppression costs are significantly affected by perfect information on fire behavior conditions, total cost plus loss is only moderately affected by that additional information. Most of the FIRESCOPE savings would have occurred under a system that had a relatively simple level of fire perimeter modeling.

4. Reductions in Cost Plus Loss During Multifire Situations

Much attention has been given to the problem of resource availability and allocation during multifire situations. The problem was particularly acute during the 1970 fire season, for example, when it was estimated that over 10,000 men and 1,000 pieces of equipment were being used from almost every fire protection agency in Southern California. It is of interest to examine the effect that FIRESCOPE would have had on coordinating and allocating the resources during the 1970 fire season.

Five of the 16 fires in our survey occurred during the 1970 fire season. As identified in Appendix A, FIRESCOPE would have allowed for a measurable improvement in cost plus loss on each one of the five fires. Most of the savings, however, would have been the result of improved suppression planning on the individual fires. In only two instances were part of the savings a result of increased availability of regional resources due to improved allocation among the various fires.

In one instance, on the Laguna fire, the California Division of Forestry (CDF) commander requested additional resources for the protection of urban areas about 24 hours before the fire actually arrived there. He was told that he would have to wait on his request because it was still not certain that the fire would reach the San Diego suburbs and because all the available resources were currently being used on the Clampitt fire in the Los Angeles area. The resources finally arrived the next day, but the commander felt that if the resources had been dispatched when he originally requested them, he would have been able to prepare a better defensive effort and thereby save about 25 additional houses. He felt that if the resource inventory function of FIRESCOPE had been operational, it might have been able to locate some additional resources for his request. He also felt that a formal perimeter modeling function would have documented and emphasized his request and therefore given him more credibility and a better chance of obtaining the resources.

The other instance was on the Buckeye fire, where a request was made for resources to help defend a major ridgetop. The incident commander was told that the region could not make a firm commitment of resources to the Buckeye fire because several other major fires were burning in Southern California. As a result, the decision was made to defend a more distant ridgetop. In fact, many of the requested resources arrived at the designated time. If it had been known that the resources were going to arrive then, the decision would have been to defend the first ridgetop, giving an 80 percent chance of saving 6,500 acres.

Those were the only two instances in the 1970 fire season where we could identify specific savings attributable to the regional resource inventory function. There were definite constraints on resource availability during the 1970 fires, but it was generally felt by the incident commanders we interviewed that most of the fires would have burned the way they did even if more resources had been available. If it had been operational, the regional resource inventory function might have resulted in other improvements on the 1970 fires, such as reducing travel time or improving the match between type of equipment requested and type of equipment sent. However, the identification of these savings would have required a detailed analysis of the fire records and was not undertaken because inventory control was already a firmly established element of the FIRESCOPE system.

5. A Fire That Would Have Been Little Affected by FIRESCOPE

Of the 16 fires analyzed, one would have remained unchanged even if FIRESCOPE had been operational. That was the Dry Gulch fire that burned in the Angeles National Forest and Los Angeles County in September 1974. The fire burned about 5,800 acres in a relatively inaccessible area. The fire was finally contained when it reached a network of roads, and it was judged by senior officers on the fire that it would have burned to the roads even if FIRESCOPE had been present.

The Dry Gulch fire is important because it shows that there are fires in which FIRESCOPE would have little effect on fire losses and suppression costs. In some cases, the burn area is inaccessible; in others, the fire conditions are too severe to be controlled with present-day technology; and in other cases, the required suppression effort is routine enough to require little additional formal assistance. A subsequent section in this chapter will attempt to determine the fraction of past Southern California fires in which FIRESCOPE would have had little effect.

6. Lead Time Required for Perimeter Prediction

Of interest to the designers of the FIRESCOPE system is the length of time over which perimeter predictions must be given. This is a complex problem as it depends on a number of factors, including: the point of interest, build-time, available resources, and accuracy of the prediction system itself. We did not examine this question in detail, but during the course of our analysis we developed an inventory of lead times for particular fire situations.

Table 10 lists the lead times that were identified on each of the 16 fires. The list is by no means comprehensive. Our analysis focused on the strategic decisions that might have been changed if different levels of information had been available. It did not investigate tactical decisions, and presumably some of those decisions would have benefited from perimeter prediction. Thus, the table should be viewed as a partial sample of the lead times that might be required in a major fire.

The table also indicates whether a computerized perimeter prediction would have resulted in additional savings at the point of interest; and, if so, it gives the minimum level of accuracy required to achieve the savings. The latter two columns are interesting because when compared with the estimated lead time they show how accuracy requirements depend on lead time. For the situations where a nonperfect perimeter prediction (α = 1/2, 1/3, 1/6) resulted in savings, the lead times varied from 1 to 24 hours. Most of the lead times for those cases were less than 12 hours, however. Lead times of less than 3 hours did not always correlate with highly accurate perimeter prediction requirements. In the Soboba fire, for example, it was judged that an α = 1/2 system was sufficient, even though the lead time was 2-1/2 hours, because the need was primarily to document a manual prediction that had already been made.

7. The Importance of Fuel and Weather in Fire Control

Table 11 lists the principal factors for controlling each of the 16 fires. The table shows that only the Dry Gulch and possibly the Soboba and Stewart fires were controlled primarily because of suppression efforts. The other fires were controlled either after they ran out of fuel or the wind stopped. The implication is not that suppression efforts are ineffective, but rather that once a fire has escaped and is burning under extreme conditions, there is little that can be done to control it until the wind dies down or the fuels run out. When one of those events has occurred, suppression forces can move in and begin to control the fire.

Table 12 summarizes the importance of weather shifts on the 16 fires that adversely affected the fire losses. The table shows that 7 of the 16 fires experienced weather shifts that led to further losses. Six of the seven shifts were not predicted, and in five of those six fires, it was judged that a perfect prediction on the shift would have resulted in a reduction of at least 10 percent in the cost plus loss of the fire. In four of those five cases a correct prediction on the weather shift would have enabled the forces to prepare in advance for the shift, and in the fifth case (Romero fire) there would have been an opportunity to take advantage of a temporary break in the weather. Thus, it is apparent that having the capability to predict major shifts in the weather could lead to measurable benefits in reducing fire costs and losses.

Table 10

SELECTED LEAD TIMES FOR PERIMETER PREDICTION FOR 16 FIRES

Fire	Point of Interest	Time of Decision	Time of Fire Arrival	Lead Time (hours)	Would a Computerized Perimeter Prediction Have Resulted in Additional Savings at Point of Interest?	If Yes, What Was Minimum Level of Accuracy Required?
Potrero	State Park	3:00 pm	5:00 pm*	2	No	--
	Big Sycamore Canyon	3:00 pm	5:00-6:00 pm	2-3	No	--
Romero	Intermediate ridgetops	Morning	Afternoon	9-15	Yes	$\alpha = 1/3$
Bear-LP	Ojai	10:00 am	4:00 am*	32	Yes	Perfect
Coyote	Camino Cielo	6:00-10:00 pm	2:00 pm	18-22	No	--
	Santa Barbara front	Afternnon	Evening	2-6	Yes	$\alpha = 1/6$
	Santa Ynez	Evening	Afternoon	20-24	Yes	$\alpha = 1/2$
Wellman	Manzana Creek	Not identifiable	Not identifiable	20-24	Yes	$\alpha = 1/2$
Buckeye	Brush-covered ridge	Early evening	Late evening	6-8	Yes	Perfect
Soboba	Indian Truck Trail	12:00 noon	2:30 pm	2.5	No	--
	Banning-Idylwild Highway	3:30 pm	6:00 pm	2.5	Yes	$\alpha = 1/2$
Bear-SB	Smiley Park	10:00 am	10:00 pm	12	Yes	$\alpha = 1/2$
Rolling Hills	Portuguese Bend	3:00-4:00 pm	5:00-5:30 pm	1-2	Yes	$\alpha = 1/2$

Table 10 (Concluded)

Fire	Point of Interest	Time of Decision	Time of Fire Arrival	Lead Time (hours)	Would a Computerized Perimeter Prediction Have Resulted in Additional Savings at Point of Interest?	If Yes, What Was Minimum Level of Accuracy Required?
Dry Gulch	Tapia Canyon Road	Afternoon	Afternoon	3-4	No	--
Wright	Malibu Beach	10:00 am	6:00-7:00 pm	8-9	No	--
Topanga	Fernwood	6:00-8:00 pm	9:00 pm*	1-3	No	--
	Topanga Canyon Boulevard	Afternoon	10:00 pm	4-6	No	--
Laguna	Japatul Road	10:00 am	2:00 am	16	Yes	$\alpha = 1/2$
	Suncrest	Afternoon	Afternoon	24-28	No	--
Boulder	No points of interest identified	--	--	--	--	--
Stewart	San Juan Station	6:00 pm	12:00 pm	6	No	--
Paseo Grande	Orange Park	12:00 pm	4:00-5:00 pm	4-5	Yes	$\alpha = 1/2$

*Fire never arrived at point of interest but the time listed was the most likely estimate at time of decision.

Table 11

PRINCIPAL FACTORS IN CONTROLLING THE 16 FIRES

Fire	Was the Suppression Effort the Primary Factor in Controlling the Fire?		If No, What Was the Principal Factor in Controlling the Fire?	
	Yes	No	No More Fuel	Wind Stopped
Potrero		x	x	x
Romero		x		x
Bear-LP		x	x	x
Coyote		x		x
Wellman		x		x
Buckeye		x		x
Soboba	?	x	x	
Bear-SB		x		x
Rolling Hills		x		x
Dry Gulch	x			
Wright		x	x	
Topanga		x	x	x
Laguna		x	x	x
Boulder		x		x
Stewart	?	x		x
Paseo Grande		x	x	

Table 12

THE IMPORTANCE OF WEATHER SHIFTS ON THE 16 FIRES

Fire	Did a Major Change in the Weather Occur During the Fire That Adversely Affected Losses?		Was the Change Predicted?		If Not Predicted and a Perfect Prediction Was Available, Could the Cost Plus Loss Have Been Reduced by at Least 10 Percent?	
	Yes	No	Yes	No	Yes	No
Potrero		x				
Romero	x			x	x	
Bear-LP	x			x		x
Coyote	x			x	x	
Wellman		x				
Buckeye	x			x	x	
Soboba		x				
Bear-SB		x				
Rolling Hills	x			x	x	
Dry Gulch		x				
Wright		x				
Topanga		x				
Laguna	x		x			
Boulder		x				
Stewart	x			x	x	
Paseo Grande		x				

8. The Maximum Amount That Could Justifiably Be Spent on Each Alternative

Detailed estimates of the development, acquisition, and operating costs for the various FIRESCOPE alternatives were not available for this analysis. Therefore, it was not possible to identify the most attractive alternative. However, as one measure of the maximum amount that could justifiably be spent on FIRESCOPE, we can calculate the present value of the savings that would occur under each FIRESCOPE alternative.

For the purpose of this calculation we will assume that the present average rate of annual cost plus loss ($43.4 million per year) will continue if no FIRESCOPE system is implemented at all. We will also assume that the reduction factors calculated for the 16 fires apply to all major Southern California wildfires. The resultant expected annual savings are given in Table 13 for each alternative.

To calculate the total value of the savings in present dollars, we must discount the value of the future savings to reflect the time value of money. Following the practice of many government agencies, including the Office of Management and Budget, we will use a 10-percent discount rate to discount future dollars. Table 13 gives the total value of the savings over a 15-year period in present dollars for each alternative. The 15-year period was selected because of possible obsolescence of the initial FIRESCOPE system and because the present value of savings in subsequent years would be relatively small.

The table shows that up to an expected $60.8 million in present dollars could be saved under improved situation assessment. The addition of a simple perimeter prediction model would increase the present value of the expected savings to $75.8 million. An addition of $3 million in present expected dollars would be saved by increasing the level of perimeter accuracy from $\alpha = 1/2$ to $\alpha = 1/6$. Thus, it would not be justifiable to significantly increase the accuracy on time of fire arrival in the perimeter prediction model if that effort cost more than $3 million.

Table 13

PRESENT VALUE OF SAVINGS UNDER FIRESCOPE ALTERNATIVES

	1	2	3	4	5	6	7
Calculated reduction factor for 16 fires (percent)	0.0%	18.6%	19.5%	23.3%	23.3%	24.2%	25.3%
Expected annual cost plus loss, if above factors apply to all major Southern California wildfires (millions of dollars)	$43.4	$35.3	$34.9	$33.3	$33.3	$32.9	$32.4
Expected annual savings in cost plus loss (millions of dollars)	0.0	8.1	8.5	10.1	10.1	10.5	11.0
Present expected value of savings at 10 percent discount rate over 15-year period (millions of dollars)	0.0	60.8	64.3	75.8	75.8	78.8	82.6

B. Survey of 86 Southern California Wildfires

The 16 fires just analyzed were selected for study because they were judged by the FIRESCOPE Task Force to be good examples of the kinds of fires in which FIRESCOPE would have had a major impact. They were not selected as being necessarily representative of Southern California experience; indeed, there was speculation that the 16 fires would show a higher rate of savings than the overall Southern California average. It was therefore decided to check the results of the 16-fire analysis by undertaking a broad survey of as many fires as possible.

This section summarizes the results of a broader survey of Southern California wildfires. The purpose of the survey was to identify the FIRESCOPE functions that would have been needed on each fire and to check the total maximum savings achievable under FIRESCOPE. By necessity, the survey was not carried out in as much detail as the 16-fire survey. But since it was completed by the same fire officials who had collaborated on the 16-fire survey, it was felt that their assessments on the total savings were reasonable judgments on the savings that might occur. The survey ultimately covered the 86 fires listed in Tables 15 and 16. (The Angeles National Forest was not included in the survey because there were no Angeles fires in the original sample of 16 fires. While the draft version of this report was being circulated for review, we had an opportunity to survey 23 fires in the Angeles National Forest. The results of that survey are reported separately in Appendix F, because Richard Montague, the officer who participated in the survey, did not participate in the 23 fires.)

Individual value assignments for structural and acreage-related losses were not obtained for each fire. Thus, to determine the cost plus loss for each fire it was necessary to use the value classification scheme developed in SRI's first FIRESCOPE project.[1] The value scheme is summarized in Table 14.

That scheme focused on the amount of acreage burned and number of houses destroyed and then extrapolated to account for other related losses. Thus, for example, housing-related losses were set at 2.68 times the actual value of the house, to account for the loss of contents, uninsured losses, and the overhead cost of providing insurance. Watershed values were incremented by $35 to $65 per acre to account for damage to aesthetics, wildlife, recreation, nonstructural improvements, and disruption of normal business patterns.

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[1] D. W. North, F. L. Offensend, and C. N. Smart, "An Economic Evaluation of Multi-Agency Communication and Coordination Systems for Southern California: A Preliminary Assessment," Stanford Research Institute, Menlo Park, California (February 1974).

Table 14

VALUE ASSIGNMENTS USED IN SURVEY OF 86 FIRES

Category			Value Assignments		
Fire Classification	Level of Structural Exposure	Value of Watershed Area	Acreage-Related† Losses per Burned Acre	Housing-Related‡ Losses per Destroyed House	Suppression Costs per Burned Acre
A, A*	Low	Low	$ 60	$ 53,600	$45
B, B*	Low	High	285	93,800	50
C, C*	High	Low	90	80,400	50
D, D*	High	High	315	134,000	60

Note: Since the value classification scheme does not depend on the number of fires burning, the original classifications of E, F, G, H in the first SRI report have been changed to A*, B*, C*, D*.

†Includes damages to watershed, aesthetics, wildlife, and recreation, nonstructural improvements, and disruption of normal business patterns.

‡Includes losses to other structures and insurance systems costs.

Although it was recognized that the value scheme had never been tested, it was the only scheme readily available. As the total worth of FIRESCOPE depends on the savings achieved, fundamental work should be directed toward a refinement of value assignments. Sensitivity studies in the next chapter show that the total potential worth of FIRESCOPE is sensitive to value assignments, but that the relative comparison of the various alternatives is not affected by changes in the value assignments.

It should be emphasized that the 16-fire analysis was carried out using assignments that were provided by the incident commanders. These values were not always the same as the average values in Table 11. Thus, differences exist in the calculated cost plus loss for the common fires that occurred in both surveys. In a few specific fires, the differences were large, but the differences compensated over the sample of 16 fires.

1. Fires in Which FIRESCOPE Would Have Had Little Effect

The fires were first analyzed to determine whether FIRESCOPE would have had any measurable impact. Of the 86 fires surveyed, it was deemed by the incident commanders that 31 would have been unchanged, even if FIRESCOPE had been in existence. These fires, which are listed in Table 15, accounted for 5.5 percent of the total cost plus loss recorded in the 86-fire survey.

In many cases, the incident commanders provided comments as to why FIRESCOPE would have had little effect on the fires. Most of the comments indicated either that the weather conditions were so severe or the access was so limited that the fire would have burned the way it did regardless of FIRESCOPE's presence. It is interesting to note that 18 of the 31 fires where FIRESCOPE would have had little effect occurred in nonurbanized areas (fire classifications A and B). Of these fires, 11 occurred in low-value watershed areas (fire classification A); areas that probably had limited access and limited resource availability. In a few cases, the suppression effort went exactly as planned, and the incident commanders indicated that FIRESCOPE would have been of little additional assistance.

2. FIRESCOPE Capabilities Desired

Of the 55 fires where it was judged that FIRESCOPE would have had an impact, the fire officers were asked to specify the functions that would have helped lead to that impact. The desired functions are listed in Table 16. The table reveals some significant differences in the desired

Table 15

31 FIRES IN WHICH FIRESCOPE WOULD HAVE HAD LITTLE EFFECT

Fire	Fire Classification	Acres Burned	Dwellings Lost	Suppression Costs (1970 dollars)	Total Cost Plus Loss (1970 dollars)
Cleveland National Forest					
Guejito (1950)	D*	5,630	0	$337,800	$ 2,111,250
San Ysidro (1954)	A	5,925	0	266,625	625,125
Black Mountain (1961)	D	9,050	0	543,000	3,393,750
Woodchuck (1964)	C	1,440	0	72,000	201,600
San Bernardino National Forest					
Cable Canyon (1954)	D	3,854	0	231,240	1,445,250
Morse (1957)	B	2,400	0	120,000	804,000
Sandstone (1959)	A	8,612	0	387,540	904,260
Jenson (1966)	A	2,700	0	121,500	283,500
Rock House (1966)	A	1,390	0	62,550	145,950
Pilot (1969)	B	1,380	0	69,000	462,300
Waterman (1970)	D	1,345	0	80,700	504,375
Cucamonga (1970)	B*	2,850	0	171,000	954,750
Los Angeles County					
Hacienda (1955)	D	1,150	0	69,000	419,750
Wiley Canyon (1957)	A	1,800	0	81,000	189,000
Warner (1958)	A	4,040	3	181,800	588,150
Soledad (1959)	A	2,200	0	99,000	231,000
Whitting Woods (1964)	D*	6,754	0	405,240	2,532,750
Chevy Chase (1964)	D*	2,315	0	138,900	868,125
Bee (1965)	A	1,103	0	49,635	115,815
Palmer (1967)	C*	14,115	10	635,175	2,780,100
Turnbull #2 (1967)	D*	1,720	1	103,200	779,000
Latigo (1967)	C*	2,870	5	143,000	803,800
Brown (1968)	A	1,785	0	80,325	187,425
Weldon (1969)	B	4,010	0	200,500	1,343,350
Shanon (1970)	C*	2,490	0	124,500	348,600
San Francisquito (1970)	A*	4,390	0	197,550	460,950
Val Verde (1970)	A*	7,280	0	327,600	764,400
Orange County					
Weegand (1954)	B	1,331	0	66,550	445,885
Niger (1955)	B	1,155	0	57,750	386,925
Kelly (1958)	B	2,561	0	128,050	857,935
Ventura County					
Sence Ranch (1967)	D*	17,431	0	1,045,860	6,536,625
Total cost plus loss for 31 fires					$32,112,395

Note: For value classifications, see Table 14.

Table 16

DESIRED FIRESCOPE FUNCTIONS FOR 55 FIRES

Fire	Fire Classification	Total Cost Plus Loss (dollars)	Common Training, Terminology, Procedures, and Organizational Standards	Improved Communication and Coordination	Computerized Regional Resource Inventory	Computerized On-Site Resource Inventory	Perimeter Modeling
Cleveland National Forest							
Morrell (1950)	D	$ 1,990,250					x
Conejos (1950)	D	26,969,500					x
Aqua Tibia (1950)	A*	224,910					x
Banner (1950)	D	739,875					x
Jameson (1954)	D	2,607,375					x
Pine Mountain (1956)	A*	774,950	x				x
Cornwell (1956)	A*	311,850					x
Inaja (1956)	D	16,866,000	x	x			x
Pederson (1957)	B	693,750					x
Chocolate (1957)	D	1,423,500					x
Pala (1958)	A	176,400					x
Stewart (1958)	D	27,488,500					x
Decker (1959)	D	526,875	x				
Pleasants (1960)	A*	318,250	x	x			x
Outside (1961)	D	288,330					x
Vail (1968)	B	501,830					x
Pechanga (1968)	B	782,560	x	x			x
Magee (1968)	A	204,855					x
San Mateo (1969)	A	1,768,200					x
Laguna (1970)	D*	116,970,500			x	x	x
Boulder (1970)	D*	5,507,500					x
Los Padres National Forest							
White Mountain (1960)	B*	4,090,350		x	x	x	x
Coyote (1964)	D	39,865,000	x	x	x	x	x
Wellman (1966)	A	9,828,000	x	x	x	x	x
School House (1966)	A	354,375		x			x
Timber Canyon (1967)	D*	4,182,170	x	x	x	x	x
Poplar (1970)	B	422,100		x	x	x	x
Buckeye (1970)	D*	18,510,000	x	x	x	x	x

Table 16 (Concluded)

Fire	Fire Classification	Total Cost Plus Loss (dollars)	Common Training, Terminology, Procedures, and Organizational Standards	Improved Communication and Coordination	Computerized Regional Resource Inventory	Computerized On-Site Resource Inventory	Perimeter Modeling
San Bernardino National Forest							
McKinley (1956)	D	$ 4,498,750		x		x	x
Stable (1959)	D	4,942,250		x	x	x	x
McKinley (1960)	D*	598,500		x	x	x	x
Sayles (1960)	C	926,800		x	x	x	x
Brook (1962)	D	712,500		x		x	x
Cozy Dell (1964)	D	7,251,375		x	x	x	x
Meyers (1970)	D*	14,060,000		x	x	x	x
Bear (1970)	D*	21,252,500		x	x	x	x
Los Angeles County							
Twin Lakes (1954)	B	782,225	x	x			
Latuna (1955)	D*	1,571,690	x	x		x	
Sherwood (1956)	C*	1,963,120	x	x	x	x	x
Newton (1956)	C*	7,683,800	x	x	x	x	x
Hume (1956)	D*	1,933,500		x		x	
Haskett (1958)	C	1,373,800	x	x		x	
Liberty (1958)	D	10,047,500	x	x	x	x	x
Mulholland (1958)	D	11,784,250	x	x		x	
Bel Air (1961)	D*	67,139,750	x	x	x	x	
Topanga (1961)	D*	3,804,125	x	x	x	x	
Golden (1962)	A*	1,010,045				x	
Onandarka (1962)	D*	9,995,500	x	x	x	x	
Weldon (1964)	A*	320,250	x	x			
Wright (1970)	D*	24,273,875	x	x	x	x	
Clampitt (1970)	D*	51,710,125	x	x	x	x	
Ventura County							
Parker Ranch (1967)	D*	9,375,000		x	x	x	
Ditch Road (1967)	D*	554,000		x	x	x	
Ventura City Foothill (1970)	D*	2,367,375	x	x	x		
Guiberson (1970)	D*	4,642,875		x	x	x	

functions among the various agencies. For example, relatively little need was indicated in the Cleveland National Forest for formal assistance in situation assessment; but there was a major need for a fire modeling capability. In contrast to the Cleveland National Forest, Los Angeles County indicated relatively little need for a formal fire modeling capability, but a major need for situation assessment. The differences are probably a result either of misinterpreting the questionnaire or of inherent differences in the characteristics of the areas and personalities involved, both of which lead to differences in the style of suppression effort. In spite of the different functions that were indicated as being desirable, we believe that the indicated total potential savings for each fire are a reasonable approximation of the true potential, because the savings were estimated on the basis of specific points of interest that could have been saved if the suppression effort had been more effective.

There was an indicated need for improved situation assessment in approximately three-fifths of the fires. Of the 55 fires in which FIRESCOPE would have had an effect, 36 had a need for improved communication and coordination; 25 needed regional resource inventory; and 31 needed on-site resource inventory.

There was an indicated need for a fire modeling capability in about 70 percent of the fires where it was deemed FIRESCOPE would have had an effect. We attempted to use the questionnaire to quantify the level of accuracy needed, but found in many cases, through subsequent phone calls, that the question was misinterpreted. It was difficult to retain the difference between the level of accuracy needed to change a decision and the level of accuracy needed to model the detailed characteristics of the fire. It appears that personal interviews are required to ensure that the level of accuracy is specified according to its effect on strategic decisions.

3. Calculated Savings for Fires Surveyed

For each fire where it was judged that FIRESCOPE would have had an impact, the incident commanders were asked to estimate the number of houses and amount of acreage and suppression costs that could have been saved if the desired functions had been available during the fires. The detailed savings are listed in Appendix C. These savings were translated into their effect on cost plus loss, and the resultant calculations are given in Table 17. The table gives the cost plus loss that actually occurred on each fire and the estimated savings that would have occurred if the desired FIRESCOPE functions had been available.

Table 17

MAXIMUM POTENTIAL SAVINGS UNDER FIRESCOPE FOR 55 FIRES
(1970 Dollars)

Fire	Fire Classification	Actual Cost Plus Loss	Incident Commander's Estimate of Savings	Estimated Cost Plus Loss Under FIRESCOPE
Cleveland National Forest				
Morrell (1950)	D	$ 1,997,750	$ 59,640	$ 1,938,110
Conejos (1950)	D	26,969,500	573,300	26,396,200
Aqua Tibia (1950)	A*	224,910	208,845	16,065
Banner (1950)	D	739,875	23,675	716,200
Jameson (1954)	D	2,607,375	83,400	2,523,975
Pine Mountain (1965)	A*	774,950	133,965	640,985
Cornwell (1956)	A*	311,850	26,730	285,120
Inaja (1956)	D	16,866,000	2,304,830	14,561,179
Pederson (1957)	D	693,750	22,200	671,550
Chocolate (1957)	D	1,423,500	202,010	1,221,490
Pala (1958)	A	176,400	30,240	146,160
Stewart (1958)	D	27,488,500	9,559,750	17,928,750
Decker (1959)	D	526,875	8,430	518,445
Pleasants (1960)	A*	318,250	307,700	10,550
Outside (1961)	D	288,330	32,950	255,380
Vail (1968)	B	501,830	37,450	464,380
Pechanga (1968)	B	782,560	72,930	709,630
Magee (1968)	A	204,855	13,170	191,705
San Mateo (1969)	A	1,768,200	732,540	1,035,660
Laguna (1970)	D*	116,970,500	0	116,970,500
Boulder (1970)	D*	5,507,500	435,375	5,072,125
Los Padres National Forest				
White Mountain (1960)	B*	4,090,350	4,080,825	9,525
Coyote (1964)	D	39,865,000	11,926,000	27,939,000
Wellman (1966)	A	9,828,000	1,123,200	8,704,800
School House (1966)	A	354,375	45,600	308,775
Timber Canyon (1967)	D*	4,293,000	2,318,220	1,974,780
Poplar (1970)	B	422,100	3,150	418,950
Buckeye (1970)	D*	18,510,000	4,795,000	13,715,000

Table 17 (Concluded)

Fire	Fire Classification	Actual Cost Plus Loss	Incident Commander's Estimate of Savings	Estimated Cost Plus Loss Under FIRESCOPE
San Bernardino National Forest				
McKinley (1956)	D	$ 4,498,750	$ 2,584,375	$ 1,914,375
Stable (1959)	D	4,942,250	3,692,860	1,249,390
McKinley (1960)	D*	598,000	280,100	318,400
Sayles (1960)	C	926,800	198,600	728,200
Brook (1962)	D	712,500	95,475	617,025
Cozy Dell (1964)	D	7,251,375	2,004,675	5,246,000
Meyers (1970)	D*	14,060,000	7,191,200	6,868,800
Bear (1970)	D*	21,252,500	2,045,900	19,206,600
Los Angeles County				
Twin Lakes (1954)	B	782,225	59,605	722,620
Latuna (1955)	D*	1,614,750	484,490	1,130,260
Sherwood (1956)	C*	1,963,120	519,570	1,443,550
Newton (1956)	C*	7,683,800	2,742,760	4,941,040
Hume (1956)	D*	1,933,500	109,125	1,824,375
Haskett (1958)	C	1,373,800	298,180	1,075,620
Liberty (1958)	D	10,047,500	1,205,750	8,841,750
Mulholland (1958)	D	11,918,250	7,971,220	3,813,030
Bel Air (1961)	D*	67,139,750	52,543,125	14,596,625
Topanga (1961)	D*	3,804,125	1,114,595	2,689,530
Golden (1962)	A*	1,010,045	860,795	149,250
Onandarka (1962)	D*	9,995,500	9,397,885	597,615
Weldon (1964)	A*	320,250	36,345	283,905
Wright (1970)	D*	24,273,875	6,248,375	18,025,500
Clampitt (1970)	D*	51,710,125	12,593,350	39,116,775
Ventura County				
Parker Ranch (1967)	D*	9,375,000	8,906,250	468,750
Ditch Road (1967)	D*	554,000	533,000	21,000
Ventura City Foothill (1970)	D*	2,367,375	491,265	1,876,110
Guiberson (1970)	D*	4,642,875	2,321,595	2,321,280
Total for 55 fires		$551,258,625	$165,691,575	$385,567,050

The reported savings in cost plus loss vary from less than 5 percent to 99 percent, depending on the fire. On the average, the cost plus loss for the 55 fires would have been reduced by 30.0 percent if the desired FIRESCOPE capabilities had been available. The 55 fires accounted for 94.5 percent of the cost plus loss for all 86 fires, and combining the savings for the 55 fires with the 31 fires in which FIRESCOPE would have had no effect gives a 28.4 percent savings in cost plus loss for the 86 fires surveyed:

$$(0.945 \times 0.30) + (0.055 \times 0.00) = 0.284 \quad .$$

The 28.4 percent figure just calculated is based on the raw data of the survey of 86 fires. However, there were some discrepancies in the responses for the common fires that appeared in the two surveys. Where they occurred, we believe that the discrepancies are the result of not considering the fire in as much detail during the second survey, and that the savings indicated in the 16-fire survey are more reliable. Therefore, as described in Appendix E, we developed an updating methodology to adjust the raw data in the second survey for an apparent bias due to not considering the fires in sufficient detail. The adjustment factors are calculated for each survey respondent on the basis of the discrepancies between the common fires in the two surveys. The adjustment factors are quite small, and the net effect of applying them to the raw data is to decrease the 28.4 percent reduction factor just calculated to 27.0 percent.

The 86-fire survey gives maximum potential FIRESCOPE savings of up to 27 percent. These savings are approximately the same as the maximum potential savings of 25 percent observed in the more detailed analysis of 16 fires. Thus, even though our first survey was relatively small and based on fires that were purposely selected for the survey, it appears that the sample was reasonably representative with respect to the maximum possible savings of FIRESCOPE.

Unfortunately, it is difficult to draw many other comparisons between the two surveys. Because of the limited nature of the second survey, we were not able to assign the indicated savings to particular functions if more than one function was indicated as being needed on the fire. Therefore, the result of the second survey cannot be used to quantify the differences between different levels of FIRESCOPE capabilities.

VII SENSITIVITY ANALYSIS

Our nominal analysis of the possible FIRESCOPE savings was based on the best judgment that fire officers could bring to bear on the fires. But in many cases there was uncertainty about the savings that would have occurred if a particular FIRESCOPE system had been available. Thus, in this chapter we will summarize some sensitivity studies that we performed to determine how the results of our 16-fire analysis would have changed if FIRESCOPE had allowed for different savings than nominally assumed.

Sensitivity studies were performed for each major interpretation that was suggested as an alternative to the one used in our base-case analysis. For each of these scenarios, we determined the effect that the changes would have had on the individual fires and on the total estimated savings for the 16 fires. The results of that sensitivity analysis are presented here. Detailed calculations for the sensitivity studies are given in Appendix B.

We will first summarize the individual fire changes and then give the results of some sensitivity studies based on multiple-fire changes. The multiple-fire sensitivity studies provide ranges on the maximum anticipated benefits of FIRESCOPE and on the maximum contribution of a computerized perimeter prediction system relative to a manual prediction system.

A. Single-Fire Changes

Most of the alternative scenarios we developed for the fires would have had some impact on the FIRESCOPE savings that were reported for the particular fire. However, viewed in the context of the total cost plus loss for the 16 fires, changes in only the Coyote fire savings would have had a major impact on the total reported FIRESCOPE savings.

This paragraph summarizes the three alternative scenarios for the Coyote fire. If we assume that there would have been no chance of containing the fire the first night, or at the Camino Cielo the next day, or at the Santa Ynez River the day following, then the reported savings for each of the FIRESCOPE alternatives would have been reduced by about 10 percentage points. If we attribute the possible first-night savings

to an $\alpha = 1/6$ computerized prediction system (Alternative 6) instead of to improved communication and coordination (Alternative 2) and assume that no savings were possible at the Camino Cielo or at the Santa Ynez River, then the marginal comparison between Alternatives 6 and 2 jumps from 5.6 percentage points to 13.4 percentage points. If we assume that no savings were possible the first night or at the Camino Cielo but that an $\alpha = 1/6$ computerized prediction system would have allowed for saving the houses in the front country and the possible containment of the fire at the Santa Ynez River, then the improvement in Alternative 6 over Alternative 2 for the 16 fires would have been 6.9 percentage points instead of 5.6 percentage points as nominally assumed.

These three sensitivity studies show that by shifting the possible savings on the Coyote fire, one can substantiate a wide variety of conclusions on FIRESCOPE. The assumed effect of FIRESCOPE on the Coyote fire is therefore a critical input to our analysis. Based on the many sources of information provided to us on the Coyote fire, however, we believe our nominal case to be the most plausible.

Possible changes in the Stewart fire scenario would have had a moderate effect on the calculated reduction factors for the 16 fires. In that fire, our base case assumed that improved organizational procedures would have been sufficient to recognize the threat to Ortega Highway, allowing for saving 30,000 acres and 14 houses. If we assume that a simple computerized prediction system ($\alpha = 1/2$) would have been required to realize that threat, then the marginal improvement of Alternative 4 over Alternative 3 would have increased from 3.7 percentage points to 6.0 percentage points.

We considered a number of other single-fire sensitivity studies, many of which were controversial in the context of the particular fire. For example, on the Romero fire we examined the effect of being unable to contain the fire at an intermediate ridgetop. In the Soboba fire, we considered the possibility of getting properly trained resources to the fire earlier so that there would have been a 50-percent chance of containing the fire at 100 acres. But in none of the cases was the effect of the 16 fires more than a 2-percentage point shift in the calculated reduction factors for all 16 fires.

B. Multiple-Fire Changes

1. Maximum Possible Savings of FIRESCOPE

Of the alternative scenarios examined, three attributed more savings to FIRESCOPE than nominally assumed. Combining those scenarios

gave one estimate on an upper plausible range of the maximum possible potential savings of FIRESCOPE. That exercise showed that the maximum savings of FIRESCOPE might be as high as 26.0 percent.

Two approaches were used to estimate a lower plausible range on the maximum possible savings of FIRESCOPE. Eight of the alternative scenarios assumed that not all the nominal savings would occur. So in one approach we combined all those scenarios to calculate that the maximum possible savings of FIRESCOPE might be as low as 10.3 percent.

As a second approach, we assumed that not all the identified savings on the 16 fires should be attributed to FIRESCOPE. Some of the fires occurred several years ago and, since then, a number of improvements have been made in fire-fighting technology. Thus, perhaps some of the identified savings on the 16 fires should be attributed to recent developments in technology that have already been implemented and not to FIRESCOPE.

Therefore, as a first-order attempt to account for the savings that should not be attributed to FIRESCOPE, we set the Alternative 1 losses for the pre-1970 fires (Coyote, Wellman, Stewart and Paseo Grande fires) equal to their Alternative 2 losses. The assumption was that any communication and coordination problem that occurred in 1970 and after would require the new capabilities of FIRESCOPE to ameliorate it, but that current 1975 technology would have been sufficient to solve the communication and coordination problems of the pre-1970 fires. This was a highly simplified assumption, but at least it provided some guidance as to how much of the nominally assessed Alternative 2 savings could be attributed to the results of pre-1970 fires when fire-fighting technology was not as sophisticated as it is now. The effect of the assumption was to reduce the maximum possible savings of FIRESCOPE to 12.0 percent and the savings of Alternative 2 relative to Alternative 1 to 4.1 percent.

2. Marginal Improvement of a Computerized Prediction System Over a Manual Prediction System

Three of the alternative single-fire scenarios either shifted the savings from a manual prediction system to a computerized prediction system or assigned more savings to the computerized prediction system than were nominally assumed. Combining these scenarios increased the advantage of a simple computerized prediction system over a manual system to 5.9 percentage points, compared to our nominal difference of 3.7 percentage points. This change would have made the $\alpha = 1/6$ computerized prediction system 16.4 percentage points better than Alternative 2,

because one of the Coyote fire scenarios shifted the nominal Alternative 2 savings to an α = 1/6 computerized prediction system.

Two of our scenarios shifted the nominal computerized prediction system savings to a manual system. Combining these scenarios reduced the difference between Alternative 4 and 3 from 3.7 percentage points to 0.9 percentage points. Thus, within the scope of our sensitivity analysis, the marginal improvement of a simple computerized prediction system over a manual system could range from 0.9 to 5.9 percentage points. If we attribute the possible first-night savings on the Coyote fire to an α = 1/6 computer modeling function and not to improved communication and coordination, then the savings of a computerized perimeter prediction system (α = 1/6) relative to a manual system would increase to 16.4 percent.

C. Uniform Changes in All Reduction Factors

Figure 1, drawn from Appendix B, is reproduced here to show how the results of the analysis would change if the assessed reduction factors were changed by a constant amount. Other figures are given in Appendix B showing how the results of our analysis would change with uniform changes in the acreage- and housing-related value assignments.

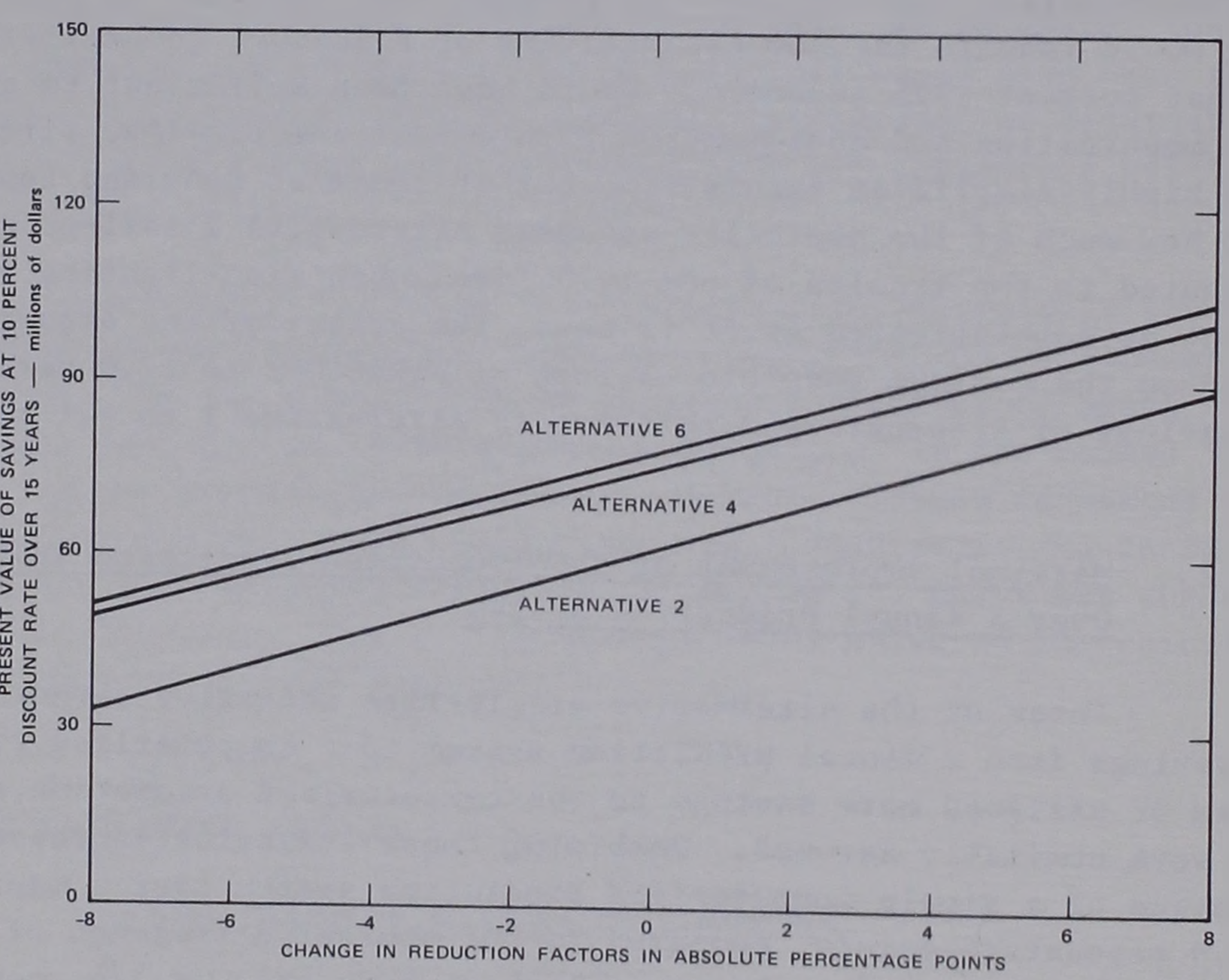

FIGURE 1 SENSITIVITY TO ADDITIVE CHANGES IN REDUCTION FACTORS

Appendix A

HISTORIES OF 16 FIRES

Appendix A

HISTORIES OF 16 FIRES

This appendix gives the fire histories for the 16 fires that were examined in detail. Also given are the base case scenarios that were used to calculate the expected FIRESCOPE savings. Other scenarios are considered in Chapter VII on sensitivity analysis. All values are expressed in 1970 dollars.

Whenever possible, value assignments were obtained from the incident commanders who collaborated on the analysis. If they were unable to provide the assignments, then we used the value assignment scheme developed in SRI's first FIRESCOPE project and summarized in Table 14 of Chapter VI. As discussed in that chapter, all housing values have been increased by a factor of 2.68 to account for losses to contents, uninsured losses, and the overhead cost of providing insurance.

1. Potrero Fire, September 26-27, 1973. Based on discussions with Donald Ellis (Ventura County Fire Department).

a. General Conditions

Weather:	Santa Ana winds, 25 mph NE
Fuel:	heavy grass, 10-year-old brush
Terrain:	rolling hills
Acreage burned:	12,800 acres
Houses destroyed:	0
Suppression costs:	$240,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$200	Donald Ellis
Other ($/acre)	35	Ellis/SRI
Total	$235	

Structural-related losses: Not applicable

c. Fire Narrative

The Potrero fire was first spotted by an air tanker working another fire that was burning in Ventura County. The tanker attempted a drop but was unsuccessful. Division Chief, Donald Ellis, was advised of the fire and quickly recognized the danger of the situation because of the Santa Ana winds, heavy grass fuels, and remoteness of the area.

While en route to the fire he requested equipment for a potentially large fire. He was hoping for 10 to 20 engines, but was not sure what would be dispatched (because of the other fires) or when the equipment would arrive.

The fire was 300 to 400 acres when he arrived 30 minutes later (2:00 pm) and spreading rapidly (1,000 to 1,500 acres per hour). His biggest concern upon arrival was determining what resources he had to work with. He was seriously limited in his actions because of a total lack of information on available resources. He felt that a resource inventory capability would have assisted him greatly on this phase of the fire.

His first major decision was to assign equipment to the structures that were being threatened on either side of the fire. It is doubtful that a formal perimeter prediction capability would have changed his decision because it was clear that the structures were being threatened.

Ellis surveyed the fire from the air and at about 3:00 pm decided to fire out Big Sycamore Canyon. That was a major strategic decision. The fire was spreading toward the ocean, but if the Santa Anas lifted and sea breezes came in, the fire would change direction and cross over Big Sycamore and run into heavy brush and areas of urban settlement. Even under the Santa Anas, the fire was spreading laterally toward Big Sycamore because of the terrain and natural spread pattern of the fire.

The western flank of the fire was not a significant problem because the area was mostly agricultural. Nothing was attempted at the front of the fire because of the intensity of the fire, the difficult terrain, and the lack of houses.

The decision to fire out Big Sycamore Canyon on the eastern flank was a major one, because it was not a routine spot to work in and it would involve firing out state park lands. Ellis was not sure what equipment would be available for the operation and how much experience the different crews (from other agencies) had.

Based on his air survey at 2:30 pm, he was virtually certain that the fire would reach Big Sycamore Creek through lateral spread by 6:00 pm, most likely between 5:00 and 6:00 pm. He variously estimated the chances of the canyon being successfully fired out between 40 and 90 percent.

At 4:00 pm, just as he was ready to start the firing operation, he was told that the fire was almost at the state park at the mouth of Big Sycamore Creek. So he pulled his trucks off the firing operation and sent them around to the park. That was a 45-minute drive. As it turned out, the fire was three miles away from the park and the call was a false alarm. Whoever reported the supposed location of the fire was deceived or confused by the heavy smoke from the fire. Ellis sent some of the equipment back to the firing operation, but he had lost two valuable hours.

The Beech King aircraft was flying over the fire taking infrared pictures. Ellis claims that if he had had those pictures during the fire, he never would have diverted his resources to the state park.

The fire finally crossed Big Sycamore Creek at 6:00.pm. Fortunately, the winds were still northeasterly, so the fire was not blown uphill into the heavy brush fields and housing areas. At 8:00 pm, Ellis decided to move his resources over to Deer Creek. They fired out the lower part of the canyon throughout the night and next morning. The fire was finally contained about noon the second day. The final perimeter was 12,800 acres.

If they had been able to hold the fire at Big Sycamore Creek, they would have saved about 2,000 acres, one seriously burned fireman, and about 36 hours of suppression and mop-up effort. Ellis claims that if he had had real-time infrared photos or if the false alarm had not come in, he would not have diverted his resources and would probably have contained the fire at Big Sycamore.

Ellis feels that with real-time infrared photos he probably could have predicted the fire perimeter as accurately as any machine. He sees the real value of perimeter prediction (including infrared photos) in documenting the information that was available to the decision maker.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Initial structural protection	Inventory management would have greatly facilitated this effort. Doubtful that fire perimeter prediction would have changed decision.
Call for more resources	Same as above.
Fire out Big Sycamore	Same as above.
Diversion of resources to state park	Real-time infrared photos would have reversed decision.
Return to Big Sycamore	Fire perimeter prediction might have reversed decision, depending upon how much time was indicated for the firing operation.
Structural protection and perimeter control at Deer Creek	Fire perimeter information would not have changed decision.

e. Calculation of FIRESCOPE Savings

If real-time infrared photos had been available, resources would not have been diverted to the state park, and 2,000 acres would have been saved, reducing acreage-related losses by $470,000 and suppression costs by a proportional amount, or $40,000.

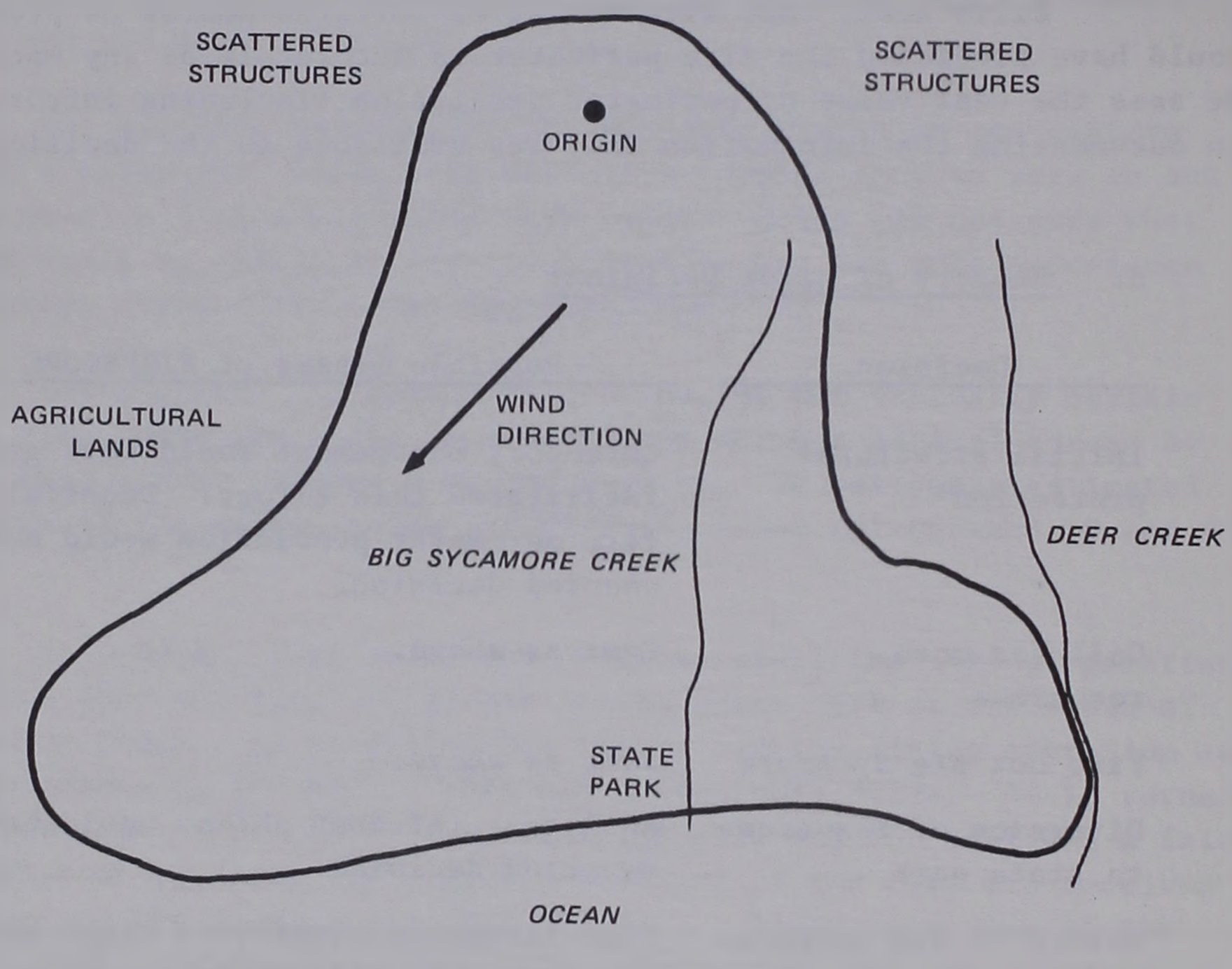

FIGURE A-1 SIMPLIFIED MAP OF POTRERO FIRE

Table A-1

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON POTRERO FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling: • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	12,800	12,800	10,800	10,800	10,800	10,800
Houses	--	--	--	--	--	--
Damage (dollars)						
Acreage	$3,008,000	$3,008,000	$2,538,000	$2,538,000	$2,538,000	$2,538,000
Houses	--	--	--	--	--	--
Suppression cost (dollars)	240,000	240,000	200,000	200,000	200,000	200,000
Total cost plus loss (dollars)	$3,248,000	$3,248,000	$2,738,000	$2,738,000	$2,738,000	$2,738,000

2. Romero Fire, October 6-16, 1971. Based on discussions with Jerry Berry and Ray Dalen (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	heavy brush
Terrain:	steep
Acreage burned:	14,538 acres
Houses destroyed:	4
Suppression costs:	$1,800,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$350	Ray Dalen
Other ($/acre)	65	Dalen/SRI
Total	$415	
Structural-related losses:	$120,600 per burned house	SRI

c. Fire Narrative

The Romero fire started under extreme burning conditions. The area had been closed to nonresidents for three days. The fire started in the front country above Santa Barbara and generally burned in an easterly direction threatening the foothill communities on the south and the Santa Ynez drainage on the north.

By the time the initial attack crews arrived, it was evident that the fire was going to escape. The fire was spreading northeasterly up the mountainside. The first major decision was to start firing the fuel break at the top of the ridge. As the fire progressed for the next 10 days, this firing effort generally proceeded slightly ahead of the fire. It is doubtful that FIRESCOPE would have changed this decision, because the fuel break was already there.

State and local forces took over the south flank. The first priority of the local crews was structural protection. Once the structural protection was well organized, the state forces began to concentrate

on perimeter control along the south flank. There was a need for improved coordination among the various agencies during the first hours of the fire, but it was difficult to single out particular savings that would have occurred because of that improvement. Four houses were lost the first night. Perhaps one house could have been saved if there had been improved coordination.

There was an old fuel break near the bottom of the mountain that was not worked. Berry said that the local forces were not equipped to undertake a major backfiring operation near urban values. Even if they had fired out the line, it might not have held. But if it had held, it probably would have saved at least 1,000 acres and four houses. The important point is that very little explicit consideration was given to that possibility. Careful preplanning, such as might occur under FIRESCOPE, might have at least generated consideration of the alternative.

Most of the major fire runs occurred at night when the winds shifted down-canyon. The sundowner effect was probably the major contributor to the spread of the fire. Four men were lost in a flare-up caused by a sundowner on the second evening of the fire.

Bulldozers were dispatched five miles ahead of the fire on the second morning. They were to start making a break running from the top of the ridge to the bottom. At the time, the decision was considered as a hedging action, in case they were not able to pinch the fire. As it turned out this line became the final perimeter.

The fire seesawed along in an easterly direction, going up and down the canyons as the winds shifted. The terrain was largely inaccessible to tractors. Intensive efforts were expended on two days trying to construct handlines up and down the mountain in an effort to pinch off the fire. The efforts failed because the fire always flared up before the line was completed. At the time, they assigned a 50 percent chance of being able to successfully pinch off the fire. Berry said that if a credible prediction had given less than a 20 percent chance of success, they probably would have changed their strategy and concentrated on firing out the area instead of pinching off the front. This change in strategy might have reduced the suppression effort by 10 to 20 percent. But on further reflection, Berry said in that circumstance they probably would have used the same number of men, and simply moved them over to a new secondary line in case the bulldozer line did not hold. So in this case, an accurate prediction might possibly have changed the strategy, but it probably would not have reduced the suppression costs. (The costs might have been reduced if it had been a multiple-fire situation, allowing the crew freed by the reduced suppression effort to be shifted to another fire.)

The fire finally burned over to the tractor line. At about the same time, the weather improved dramatically as the marine influence took over. A secondary line was also being built still further east in case the tractor line failed, but it was never used. The fire was finally contained at 14,538 acres, primarily due to the weather change and the completed tractor line from where they could work.

If perfect information on all the fire conditions (including perimeter, flame intensity, and spotting potential) had been available, the strategy might have changed to a concentrated defensive effort at an intermediate ridgetop well in advance of the fire arrival. Such an effort would have given a 50 percent chance of saving about one-half of the burned acreage, or expected savings of $0.5 \times 0.5 \times 14,538 = 3,635$ acres.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Initial flanking action along ridgetop	Decision would not have changed under FIRESCOPE.
Structural protection on south flank	Improved interagency coordination would have aided effort during first 12 hours and might have saved one house.
Perimeter control on south flank	FIRESCOPE might have shown that an alternative strategy existed, but decision probably would not have changed.
Pinching strategy on days 2 and 3	If FIRESCOPE had shown low probability of success, strategy probably would have changed to firing out entire area, perhaps reducing suppression costs by 10 to 20 percent.
Construction of tractor line on extreme eastern flank	This decision, begun as a hedging action, would have not have changed. An accurate perimeter prediction, however, would have hastened the action, perhaps reducing suppression costs by 10 percent.

e. Calculation of FIRESCOPE Savings

Improved communication and coordination would have saved one house valued at $45,000. Including insurance systems costs and savings to other improvements, the housing-related savings would have totaled $120,600.

We assume that a prediction showing that the fire was going to spread faster than the line could be built would have caused the fire boss to eliminate the pinching effort, saving about 20 percent in suppression costs, or about $400,000. To calculate the benefits of a formal prediction system, we will assume that it would have taken about 15 hours from the time of one of the planning meetings to build a line down one of the intermediate ridgetops and that it actually took the fire 12 hours to cross the ridge. Thus, under an $\alpha = 1/2$ prediction system the predicted time for the fire to cross the ridge would have been between 6 and 18 hours with 95 percent probability. From our definition of the $\alpha = 1/2$ prediction system, the prediction would have been normally distributed, with mean equal to the actual arrival time (12 hours) and standard deviation set such that two standard deviations just reached one of the outer limits of the predictable range ($2\sigma = 18 - 12 = 6$; $\sigma = 3$). Thus, from the properties of the normal distribution there would have been a 16 percent chance of the predicted time of arrival being more than 15 hours:

$$\begin{aligned} P(\text{predicted arrival time} > 15) &= 1 - N\left(\frac{15 - \mu}{\sigma}\right) \\ &= 1 - N\left(\frac{15 - 12}{3}\right) \\ &= 1 - N(1) \\ &= 1 - 0.84 \\ &= 0.16 \quad . \end{aligned}$$

By assumption, the line-building effort would have been attempted only if the predicted time of fire arrival was greater than the time to build the line. Thus, there would have been an 84-percent chance that they would not have attempted the line under an $\alpha = 1/2$ perimeter prediction system and the savings would have been:

$$(0.84 \times 400{,}000) + (0.16 \times 0) = \$336{,}000 \quad .$$

Similarly, under an $\alpha = 1/3$ prediction system there would have been a 93-percent chance of not attempting the line and the expected savings would have been $372,000. Under an $\alpha = 1/6$ prediction, the predicted time of fire arrival would have been less than 15 hours with probability 0.999 and they would almost never have attempted the line, giving a savings of $400,000.

With perfect information on fire conditions, they would have tried the intermediate pinching effort because they would have known where all the spots and spillovers were going to take place. Such a strategy would have had about a 50-percent chance of saving half the burned acreage, or expected savings of $0.5 \times 0.5 \times 14,538 = 3,635$ acres.

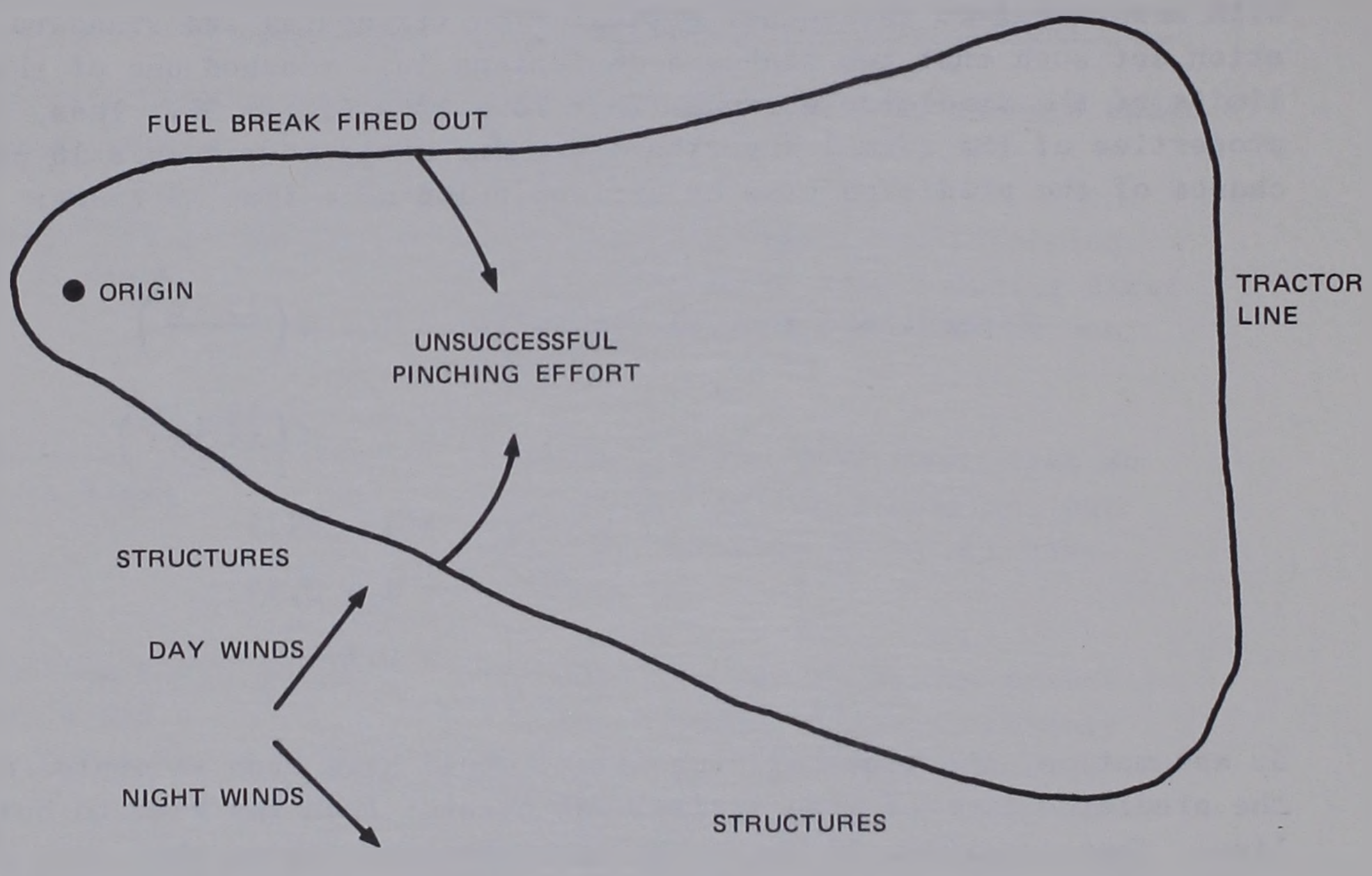

FIGURE A-2 SIMPLIFIED MAP OF ROMERO FIRE

Table A-2

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON ROMERO FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering
		• Prediction Wheel	• Computerized Prediction System ($\alpha = 1/2$)	• Computerized Prediction System ($\alpha = 1/3$)	• Computerized Prediction System ($\alpha = 1/6$)	• Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	14,538	14,538	14,538	14,538	14,538	10,903
Houses	4	3	3	3	3	3
Damage (dollars)						
Acreage	$6,033,000	$6,033,000	$6,033,000	$6,033,000	$6,033,000	$4,524,950
Houses	482,400	361,800	361,800	361,800	361,800	361,800
Suppression cost (dollars)	1,800,000	1,800,000	1,800,000	1,464,000	1,428,000	1,400,000	1,080,000
Total cost plus loss (dollars)	$8,315,400	$8,194,800	$8,194,800	$7,858,800	$7,822,800	$7,794,800	$5,966,750

3. Bear Fire, Los Padres National Forest, August 23-27, 1972.
Based on discussions with Jerry Berry and Ray Dalen (USFS).

a. General Conditions

Weather:	hot, dry, light winds
Fuel:	heavy brush
Terrain:	rugged
Acreage burned:	17,150 acres
Houses destroyed:	0
Suppression costs:	$2,200,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$250	Ray Dalen
Other ($/acre)	65	Dalen/SRI
Total	$315	
Structural-related losses:	Not applicable	

c. Fire Narrative

The Bear fire started in a fairly remote area alongside the Sespe Creek. The fuel in the area was very heavy (types 13 and 14) and had not burned in over 40 years. The weather was hot and dry and by the time the initial attack had arrived (1.5 hours after probable ignition), the fire had escaped. The fire headed up the south side of the canyon on a north facing slope and the initial efforts were directed at keeping the fire from spotting over to the north side. A direct attack was also started on the heel of the fire.

Helicopters could not be used during the night to spot the fire perimeter and personnel were sent up neighboring ridges to observe the progress of the fire. The fire reached the main ridgetop at about 12:30 am. Based on the observed rate of spread (the fire was traveling extremely fast), Ray Dalen predicted that the fire would reach the town of Ojai by 6:00 am the following day (August 25), if the fire stayed on its present course.

At about midnight on August 24 the decision was made to establish a second zone to defend the Ojai front. A number (perhaps 75) of

trucks were moved in to defend the town and begin clearing out the fuel break that surrounded Ojai.

The fire never reached Ojai. When it crossed the ridge, it changed direction and slowed down more than expected. Given the weather conditions of the first night, Berry is not sure if a computerized prediction system would have given a different prediction than Dalen or if real-time infrared photos would have caused Dalen to have changed his prediction. In any event, if it was known for sure that the fire was going to miss Ojai, then the suppression effort in that area could have probably been cut by 50 percent.

The fire camp in the Ojai zone had 2,100 men, compared to 700 men in the other camp. Apparently there was the general confusion that one might expect with 2,100 people in the same place, but we could not pinpoint how improved coordination would translate into reduced cost plus loss, given that the 2,100 men were there.

Because of the terrain and weather conditions, it is doubtful that a better fire perimeter prediction or improved coordination effort would have substantially reduced the burn area. The main impact that FIRESCOPE would have had on this fire would have been to reduce the suppression costs by perhaps 10 to 20 percent, depending on the FIRESCOPE capabilities provided.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Direct attack at heel of fire	No change in decision.
Ojai defense	A reliable prediction saying that Ojai was going to be spared would have cut this suppression effort by perhaps 50 percent in the Ojai area.
Direct attack on entire perimeter.	Basic strategy would not have changed.

e. Calculation of FIRESCOPE Savings

Improved communication and coordination, and common training, terminology, procedures, and organizational standards would have allowed for a 10-percent reduction in suppression costs, primarily because of a more efficient use of resources in the Ojai zone. Perfect information on fire conditions would have allowed for a reduced effort at Ojai, saving an additional 10 percent in total suppression costs.

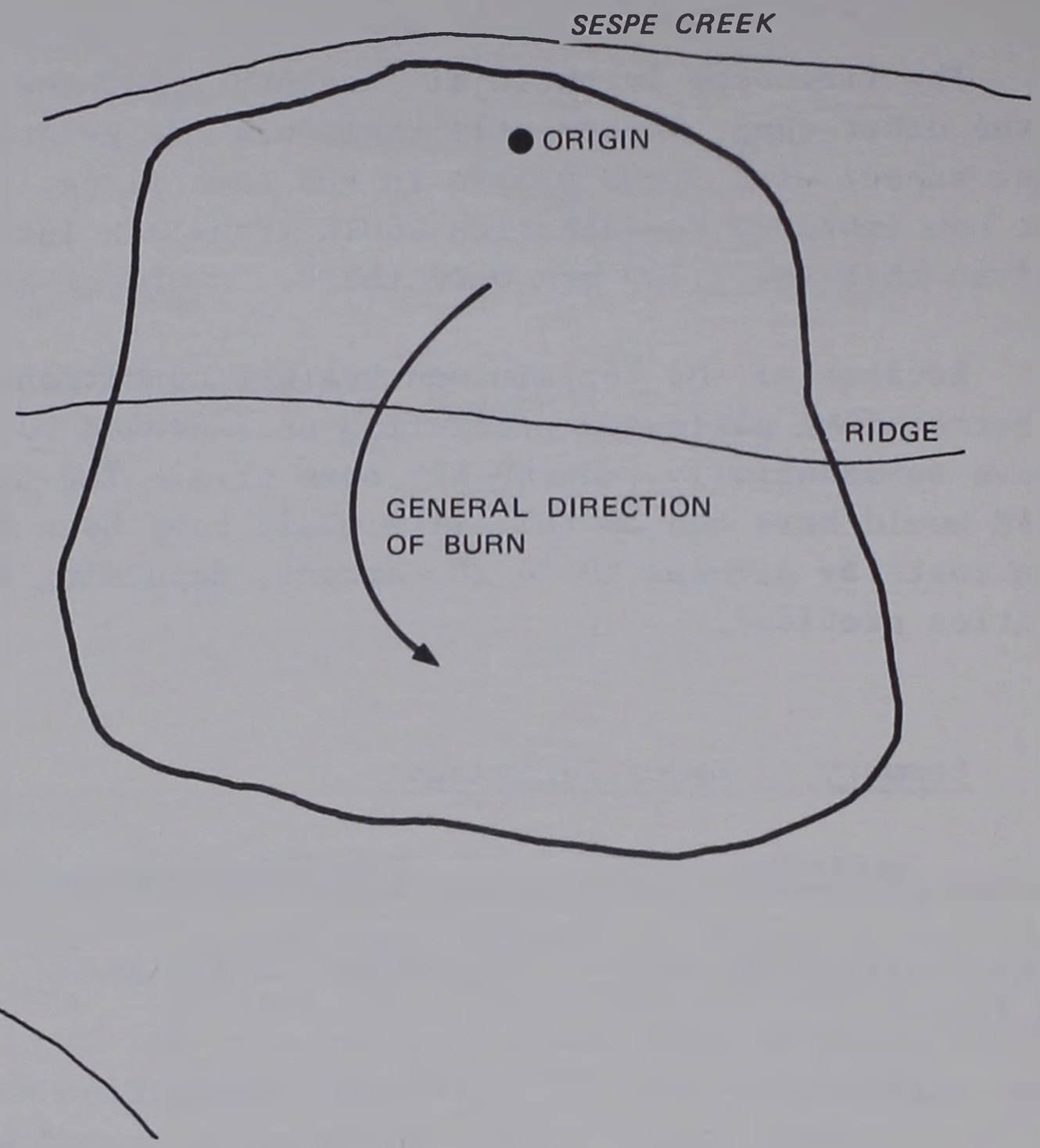

FIGURE A-3 SIMPLIFIED MAP OF BEAR FIRE, LOS PADRES NATIONAL FOREST

Table A-3

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON BEAR FIRE, LOS PADRES NATIONAL FOREST

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering
		• Prediction Wheel	• Computerized Prediction System ($\alpha = 1/2$)	• Computerized Prediction System ($\alpha = 1/3$)	• Computerized Prediction System ($\alpha = 1/6$)	• Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	17,150	17,150	17,150	17,150	17,150	17,150	17,150
Houses	--	--	--	--	--	--	--
Damage (dollars)						
Acreage	$5,402,250	$5,402,250	$5,402,250	$5,402,250	$5,402,250	$5,402,250	$5,402,250
Houses	--	--	--	--	--	--	--
Suppression cost (dollars)	2,200,000	1,980,000	1,980,000	1,980,000	1,980,000	1,980,000	1,760,000
Total cost plus loss (dollars)	$7,602,250	$7,382,250	$7,382,250	$7,382,250	$7,382,250	$7,382,250	$7,162,250

4. Coyote Fire, September 22-October 1, 1964. Based on discussions with Jerry Berry and Ray Dalen (USFS) and phone call with Carl Hickerson (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	moderately heavy brush
Terrain:	steep to rolling hills
Acreage burned:	67,000 acres
Houses destroyed:	110
Suppression costs:	$4,600,000 ($ 1970)

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$400	Ray Dalen
Other ($/acre)	65	Dalen/SRI
Total	$465	
Structural-related losses:	$120,600 per burned house ($ 1970)	SRI

c. Fire Narrative

The Coyote fire started in the foothills above Santa Barbara at about 2:00 pm. There was a considerable amount of spotting, and it was impossible to contain the fire at initial attack. By 8:00 pm the fire had burned several homes and about 300 acres, but there was a general feeling that the fire could be contained at about that size. Coordination among the various agencies during the initial hours of the fire was less than desirable, but Berry could not directly attribute any of the initial losses to poor coordination. In a subsequent discussion, Berry reiterated his thoughts on the poor interagency communication and coordination on the first day of the fire. This time, however, he said if there had been perfect interagency communication and coordination, there might have been a small chance of containing the fire at 50 acres and a few houses.

Later that evening Santa Ana winds developed and quickly fanned the fire to about 700 to 800 acres. The decision was made to focus the defensive effort on structural protection and perimeter control. Portions of the perimeter control effort did not go as planned, but because of poor field communications, the fire boss was not informed of the difficulties encountered. As a result, reinforcements were not sent in, and the perimeter was never completely contained. Hickerson said that if there had been better communication and coordination with the field he would have tried to locate some additional forces so as to reinforce the perimeter control effort. He thought that reinforcing the effort would have given a 70-percent chance of containing the fire at about 750 acres and 20 houses lost. Because of the effort along the Santa Barbara front, however, there was some question as to whether additional resources could be found. Dalen estimated that there was about a 75-percent chance of locating the necessary resources for the reinforcement effort.

According to Hickerson, it was recognized that the Camino Cielo might be threatened if the fire burned back uphill and the decision to establish a secondary effort at a 2,000-acre section along the Camino Cielo was actually considered. The effort would have required up to 500 men and 10 pieces of heavy equipment and would have involved widening the break at night and firing it out the next day if conditions had warranted it. The Camino Cielo effort was not undertaken the first night, however, because there were not enough on-site resources to undertake both the direct attack in the front country and the secondary effort at the Camino Cielo. If enough resources had been available, Hickerson said he would have undertaken the secondary effort. When asked whether a regional resource function would have been able to locate the additional resources soon enough, Hickerson said he did not know but that there was some chance that they could have been found. Berry said that if the resources had been found and mobilized in time (by midnight) and if the decision had been made to fire out the Camino Cielo, there would have been about a 50-percent chance of containing the fire at the break and saving about 45,000 acres. Hickerson did not dispute the 50-percent assessment.

The next day (September 23) the winds shifted and spread the fire back uphill. The fire crossed the Camino Cielo at about 4:00 pm, but it was a small slopover of about 90 acres. The same day, Ray Dalen and Wynne Maule made approximate calculations that the fire would spread rapidly along the Santa Barbara front country. They did not believe the prediction, but in fact the fire burned that way and burned about 90 homes along the way. Hickerson said that they were not well informed as to where the fire was actually headed during that run, and that if accurate fire spread predictions had been available, they could have saved about one-half the homes burned along the Santa Barbara front.

The winds shifted back uphill on the 24th and pushed the fire over the Camino Cielo along a broad front. The fire then burned into the Santa Ynez drainage. It crossed the Santa Ynez River and burned about 20,000 acres on the north side of the river. Hickerson and Berry thought that if a formal fire spread prediction had been available showing approximately how fast the fire would travel once it was in the Santa Ynez drainage, the decision to fire out the river bottom would have been made when the fire first crossed the Camino Cielo. That effort would have given about a 10-percent chance of saving 20,000 acres on the north side of the river.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Structural protection first afternoon	No change in decision, but improved interagency communication and coordination would have facilitated effort, giving a 10-percent chance of containing the fire at about 100 acres and 10 houses lost.
Perimeter control during first night	No change in decision, but improved communication with field would have shown need for reinforcement. If the resources could have been found, there would have been a 70-percent chance of containing the fire at 750 acres and 20 houses lost. Also, if a regional resource function had been available to locate enough additional resources by midnight, a secondary effort would have been established at the Camino Cielo, giving a 50-percent chance of saving 45,000 acres.
Structural protection along Santa Barbara front country	An accurate fire spread prediction would have allowed savings of about 45 houses.
Attempt perimeter control at Santa Ynez	A relatively crude formal prediction system would have hastened this decision, giving a 10-percent chance of saving 20,000 acres.

e. Calculation of FIRESCOPE Savings

There were opportunities for savings at three major points of interest under Alternative 2. Improved communication and coordination at the outset of the fire would have given a 10-percent chance of containing the fire at 100 acres and 10 houses lost. Given that the fire escaped initial attack (there was a 90-percent chance of it doing so), improved communication and coordination and resource inventory control would have given a $0.75 \times 0.7 = 0.54$ chance of containing the fire at 750 acres and 20 houses. Given that the fire escaped this effort [there was a $0.9 \times (1 - 0.54) = 0.42$ chance of it doing so], a computerized regional resource inventory function would have given a $0.5 \times 0.5 = 0.25$ chance of containing the fire at the Camino Cielo resulting in losses of 22,000 acres and 110 houses. Failure of the Camino Cielo effort under Alternative 2 [there was a $0.42 \times (1 - 0.25) = 0.31$ chance of it doing so] would have resulted in losses of 67,000 acres and 110 houses, as occurred. Thus, the expected acreage losses under Alternative 2 would have been:

$$= (0.1 \times 100) + (0.9 \times 0.54 \times 750) + (0.42 \times 0.25 \times 22{,}000) + (0.31 \times 67{,}000)$$

$$= 23{,}703 \text{ acres} \quad .$$

Proportional savings in suppression costs are assumed. Similarly, expected housing losses would have been:

$$= (0.1 \times 10) + (0.9 \times 0.54 \times 20) + (0.42 \times 0.25 \times 110) + (0.31 \times 110)$$

$$= 56.7 \text{ houses} \quad .$$

In addition to the acreage savings opportunities under Alternative 2, the $\alpha = 1/2$ computerized prediction system under Alternative 4 would have given a 10-percent chance of saving 20,000 acres in the Santa Ynez drainage. Thus, the expected acreage losses under Alternative 4 would have been:

$$= (0.1 \times 100) + (0.9 \times 0.54 \times 750) + (0.42 \times 0.25 \times 22{,}000) + \left(0.31\left[(0.1 \times 47{,}000) + (0.9 \times 67{,}000)\right]\right)$$

$$= 23{,}075 \text{ acres} \quad .$$

In addition to the housing savings opportunities under Alternative 2, the $\alpha = 1/6$ perimeter prediction system of Alternative 6 would

have allowed for saving 45 houses along the Santa Barbara front country, given that the fire escaped the 750-acre perimeter. Thus, expected housing losses under Alternative 6 would have been:

$$= (0.1 \times 10) + (0.9 \times 0.54 \times 20) + [0.42(110 - 45)]$$

$$= 37.8 \text{ houses} \quad .$$

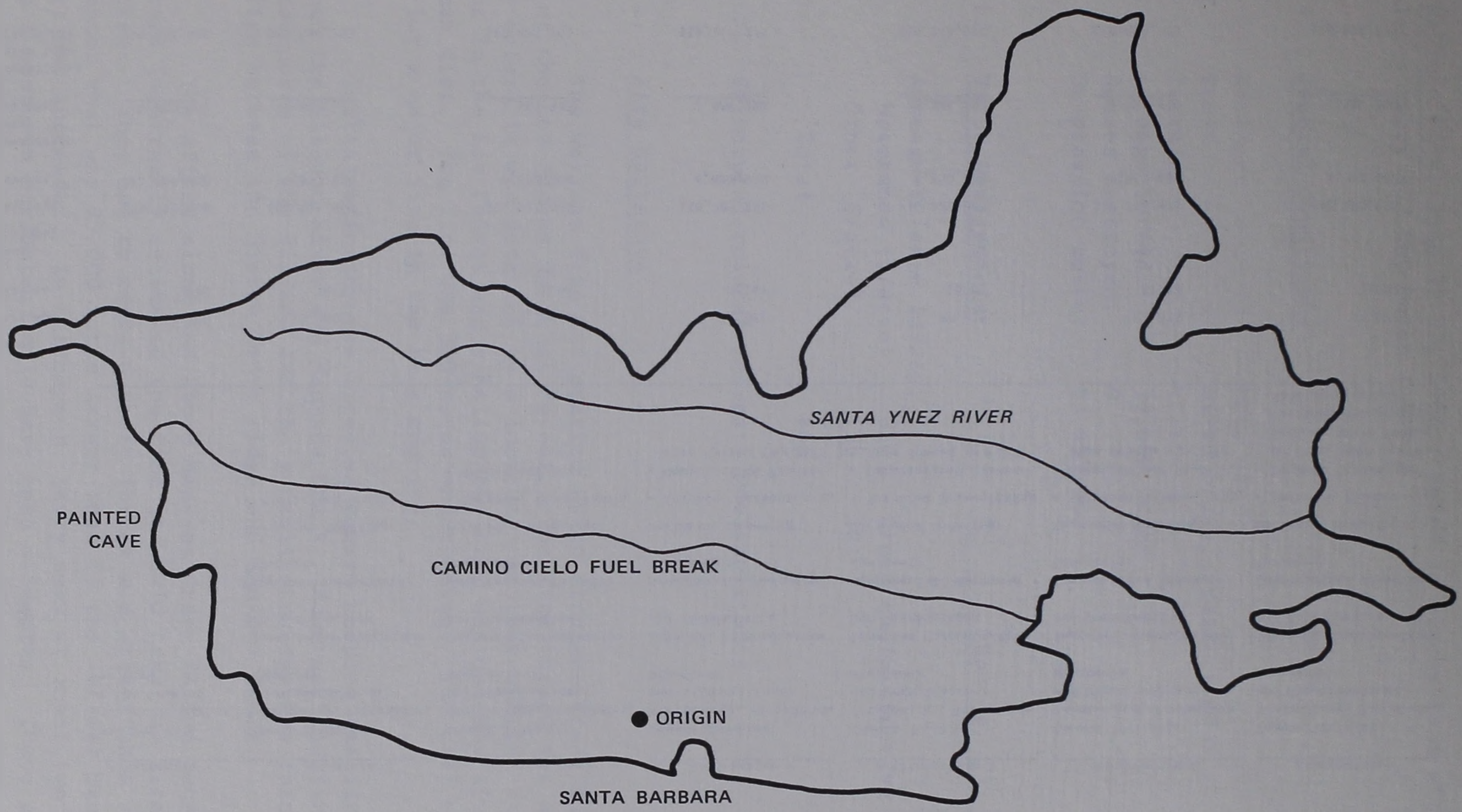

FIGURE A-4 SIMPLIFIED MAP OF COYOTE FIRE

Table A-4

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON COYOTE FIRE

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses							
Acreage	67,000	23,703.5	23,703.5	23,075	23,075	23,075	23,075
Houses	110	56.67	56.67	56.67	56.67	37.83	37.83
Damage (dollars)							
Acreage	$31,155,000	$11,021,660	$11,021,660	$10,729,875	$10,729,875	$10,729,875	$10,729,875
Houses	13,266,000	6,833,800	6,833,800	6,833,800	6,833,800	4,562,600	4,562,600
Suppression cost (dollars)	4,600,000	1,627,335	1,627,335	1,584,250	1,584,250	1,584,250	1,584,250
Total cost plus loss (dollars)	$49,021,000	$19,482,795	$19,482,795	$19,147,925	$19,147,925	$16,876,725	$16,876,725

5. Wellman Fire, June 12-22, 1966. Based on discussions with Jerry Berry and Ray Dalen (USFS).

a. General Conditions

Weather:	hot, dry
Fuel:	mixed brush, grass, timber
Terrain:	steep
Acreage burned:	93,600 acres
Houses destroyed:	0
Suppression costs:	$3,455,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$10	Draft Administrative Review
Other ($/acre)	35	SRI
Total	$45	

Structural-related losses: Not applicable

c. Fire Narrative

The Wellman fire was started by an airplane crash in a remote area of the Los Padres National Forest. The fire burned for almost 12 hours before it was detected by a lookout. Another smaller fire was being fought in the Los Padres and a helicopter crew was quickly diverted to the Wellman fire. The fire was 300 acres and running. The call was soon issued for a major fire in the back country.

Initial efforts were directed toward keeping the fire contained between the Sisquoc River and Manzana Creek. However, the fire soon spotted north of the Sisquoc and the general strategy was changed to keep the fire between the Sierra Madre ridge and Manzana Creek.

The effort along and above Manzana Creek failed because the fire officers incorrectly estimated the time it would take the fire to cross the creek. They had to regroup their forces and establish a new southerly perimeter that was 25,000 acres larger than if the initial Manzana Creek effort had succeeded. In retrospect, Berry sees at least two other places where a southern perimeter could have been attempted. These are marked A and B on the map. If they had attempted the line at A, there would have

been a 20-percent chance of holding the line, allowing for savings of 20,000 acres. Line B would have given a 100-percent chance of saving 5,000 acres.

An extensive secondary line effort was started when the initial Manzana Creek effort failed. This effort included 20 miles of oiled road that was never used. Berry feels that if a credible prediction system had been available, significant savings in the secondary line effort could have been realized, reducing the total suppression costs by at least 10 percent.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Perimeter control at Sierra Madre	No effect.
Perimeter control at Manzana Creek	If a perimeter prediction model had shown the fire was going to spread faster than estimated, then the line could have been built further south with expected savings of 5,000 to 8,000 acres.
Secondary lines and roads on western perimeter	Prediction capability would have allowed for a significant reduction in this effort, reducing total suppression costs by 10 percent.

e. Calculation of FIRESCOPE Savings

There was a 20-percent chance of saving 20,000 acres if the line was attempted at A. If the line failed, the effort still could have moved to line B, where there was a 100-percent chance of saving 5,000 acres. Therefore, the expected savings of building the line at A are:

$$(0.2 \times 20{,}000) + (0.8 \times 5{,}000) = 8{,}000 \text{ acres} .$$

The certain savings of 5,000 acres at B could have been achieved under an improved organizational structure, since all the officials had to do was to realize that B was a defensible point. The evidence indicates that very little formal effort was directed to predicting when the fire would reach Manzana Creek. Thus, they misestimated when the fire would cross the creek, but if they had had a relatively simple computerized

system ($\alpha = 1/2$) to process the available weather and fuels data, they probably would have realized how fast the fire would spread and would have moved their line back to A or B.

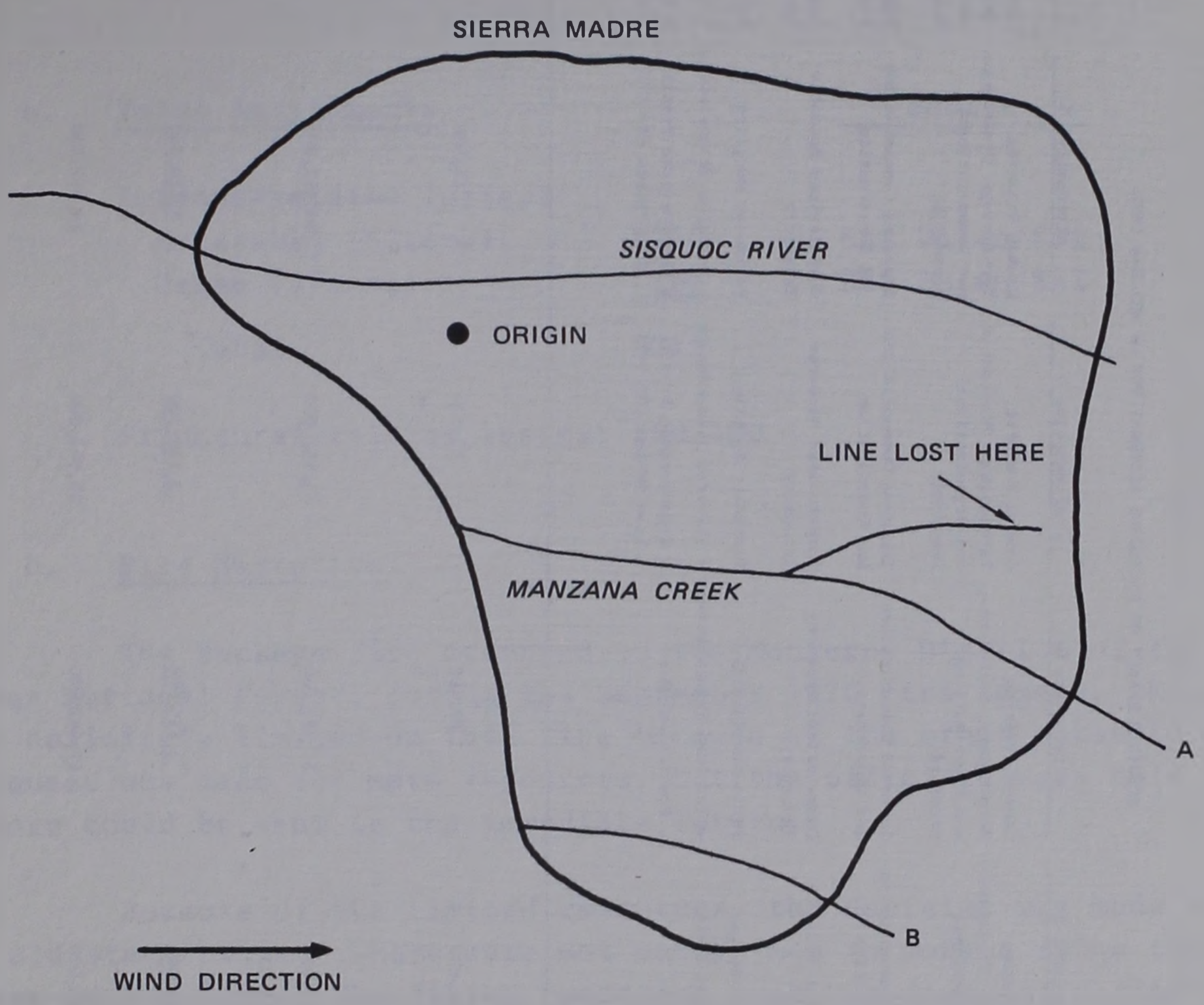

FIGURE A-5 SIMPLIFIED MAP OF WELLMAN FIRE

Table A-5

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON WELLMAN FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering
		• Prediction Wheel	• Computerized Prediction System ($\alpha = 1/2$)	• Computerized Prediction System ($\alpha = 1/3$)	• Computerized Prediction System ($\alpha = 1/6$)	• Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	93,600	88,600	88,600	85,600	85,600	85,600
Houses	0	0	0	0	0	0
Damage (dollars)						
Acreage	$4,212,000	$3,987,000	$3,987,000	$3,852,000	$3,852,000	$3,852,000
Houses	--	--	--	--	--	--
Suppression cost (dollars)	3,455,000	3,455,000	3,455,000	3,110,000	3,110,000	2,591,250
Total cost plus loss (dollars)	$7,667,000	$7,442,000	$7,442,000	$6,962,000	$6,962,000	$6,443,250

6. Buckeye Fire, September 27-October 5, 1970. Based on discussions with Jerry Berry and Ray Dalen (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	mixed brush, grass, timber
Terrain:	steep to rolling
Acreage burned:	44,000 acres
Houses destroyed:	15
Suppression costs:	$500,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$150	Ray Dalen/SRI
Other ($/acre)	165	Ray Dalen/SRI
Total	$315	
Structural-related losses:	$80,400	

c. Fire Narrative

The Buckeye fire occurred on the Monterey District of the Los Padres National Forest, during the September 1970 fire season. Resources were definitely limited on this fire because of the other fires in progress. A request was made for more resources, but the officials were told that no more could be sent in the immediate future.

Because of the limited resources, the decision was made to fire out a distant ridge. There were not enough men to work a ridge that was closer to the fire. The firing operation took two days and ultimately consumed 6,500 acres between the two breaks.

Berry feels that if they had had more men, they could have worked the closer ridge and saved 6,500 acres. Moreover, if FIRESCOPE's resource inventory system had been operating and could have told him when the reinforcements were coming, they could have staged the backfiring effort to precede the fire. In that case, they would have had an 80-percent chance of holding the line and saving 6,500 acres.

Also, if there had been an accurate perimeter and weather prediction system, they would have known that the fire was going to slow down after crossing the first break. In this case, they might have decided to fire the break with limited resources, giving them an 80-percent chance of saving 6,500 acres. The fire finally burned 44,000 acres and destroyed 15 homes.

d. Summary of Decisions

Major Decision	Possible Impact of FIRESCOPE
Fire out distant fuelbreak	A definite statement from a resource inventory capability as to when reinforcements would arrive would have changed strategy to the closer fuelbreak, giving an 80-percent chance of saving 6,500 acres. The same savings would have occurred if there had been an accurate perimeter prediction system.

4. Calculation of FIRESCOPE Savings

Expected savings of 5,200 acres (0.8 × 6,500 = 5,200) would have occurred if the decision had been made to defend the closer fuel break. Proportional savings would have occurred for suppression costs. It is likely that such a decision would have been made if either the regional resource inventory function or an accurate computerized prediction had been available.

Table A-6

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON BUCKEYE FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the Time of the Fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering
		• Prediction Wheel	• Computerized Prediction System ($\alpha = 1/2$)	• Computerized Prediction System ($\alpha = 1/3$)	• Computerized Prediction System ($\alpha = 1/6$)	• Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	44,000	38,800	38,800	38,800	38,800	38,800
Houses	15	15	15	15	15	15
Damage (dollars)						
Acreage	$13,860,000	$12,222,000	$12,222,000	$12,222,000	$12,222,000	$12,222,000
Houses	1,206,000	1,206,000	1,206,000	1,206,000	1,206,000	1,206,000
Suppression cost (dollars)	500,000	440,900	440,900	440,900	440,900	440,900
Total cost plus loss (dollars)	$15,566,000	$13,868,900	$13,868,900	$13,868,900	$13,868,900	$13,868,900

7. Soboba Fire, August 28-September 4, 1974. Based on discussions with Gene Kemble, Gene Murphy, and Robert Irwin (USFS), and Earl Young and Joseph Springer (CDF).

a. General Conditions

Weather:	severe fire weather
Fuel:	mixed grass, brush, timber
Terrain:	varied
Acreage burned:	17,683 acres
Houses destroyed:	0
Suppression costs:	$1,640,000

b. Value Assignments

Acreage-related losses:

Watershed (see discussion in "Calculation of FIRESCOPE Savings")

Structural-related losses: not applicable

c. Fire Narrative

The Soboba fire was started by an arsonist around 10:30 am. The first engine arrived at the fire at about 11:00 am and reported it would probably be able to control the fire. The dispatcher turned back the reinforcements (bulldozers), even though the preplan called for them. The fire escaped initial attack, but Kemble maintains that if the reinforcements had been sent, the fire probably could have been contained at two acres.

Ray Heibord (CDF) arrived at the fire at 11:48 am and decided to backfire the Indian Truck Trail because it was the only spot where a control line could be built. By this time, Forest Service personnel were on the fire and both agencies began backfiring the truck trail from different directions. Apparently there was a lack of coordination in this effort as one truck was nearly burned by the other crew's backfire. The fire finally crossed the trail at 2:24 pm.

Opinions vary as to whether the fire could have been contained at the truck trail. Some feel that if more experienced personnel had been assigned to the backfiring effort, it might have been successful. Others

feel that because of the wind, terrain, and fuel, the fire would have crossed the trail regardless of who was assigned to the firing effort. Still others say that if the right personnel had been assigned, the fire could have been confined to one section along the trail, where it would have gone into an old burn area and burned itself out.

The important question for this analysis is to ascertain whether any of the FIRESCOPE functions would have enabled containment of the fire at the Indian Truck Trail. Most everyone who feels that the fire could have been contained believes that more experienced personnel would have been required to successfully complete the job. The individuals who were initially assigned to the fire were immediately available and qualified by rating to undertake the effort. It seems that if more experienced personnel had been easily available, they probably would have been assigned to the fire at its outset. Thus, because the individuals who were originally assigned were fully rated for the job and because of travel time considerations it does not seem that any of the FIRESCOPE functions would have enabled containment of the fire at the Indian Truck Trail. Other assumptions on this issue are treated in the chapter on sensitivity analysis.

The incident commander, Gene Murphy, arrived at the fire at 4:30 pm. The fire was about 4,000 acres at that time and a helicopter was sent out to survey the fire. Four hundred men were requested at 4:37 pm; a firecamp had been ordered at 3:39 pm. If FIRESCOPE had been available, these important decisions might not have been delayed so long. According to Murphy and Kemble, an early arrival of the crew probably would have saved 1,500 to 2,000 acres. Others feel that an earlier arrival could have saved up to 5,000 acres.

At 3:30 pm Gene Kemble flew over the fire and predicted that it was going to be about 12,000 acres by 6:00 pm. He also predicted that the fire would cross the Banning-Idylwild Highway at that time. As it turned out, the highway was a feasible control point. According to Gene Kemble, an early decision to defend the highway would have reduced the damages significantly. There was severe spotting and he doubts that the fire could have been completely contained at the highway, but feels that there was a 95-percent chance of saving 6,000 acres of high-value timber and recreational area.

The important question for this analysis is to determine what would have caused the decision to be made to fire out the Banning-Idylwild Highway. Gene Kemble speculates that if the senior officers had arrived at the fire earlier, then possibly a decision to fire out the highway might have been made. It is not clear, however, that FIRESCOPE would have

hastened the arrival of the senior officers. A second possibility is that under improved communication and coordination, Gene Kemble's prediction would have been properly transmitted to the incident commander. This may have emphasized the need to fire out the highway, but the fact is the information was not used during the actual fire to make that decision.

A computerized prediction, however, would have provided explicit documentation on the threat to the Banning-Idylwild Highway. Such documentation would have shown the need and provided the justification for firing out the highway. Therefore, we will attribute the savings to a simple computerized prediction capability. The issue is not that a computer would produce a better prediction, but merely that it would produce a documented prediction that would help justify later actions.

The primary strategy in the evening was to hold the south flank of the fire so as to keep the fire from entering the community of Idylwild. The fire never developed a significant head at that point because of the ground suppression effort and air attack. Whether an accurate formal fire model would have reduced the suppression effort at the south flank is doubtful.

A decision was made at 3:00 am on the second morning to divide the fire into two zones. An accurate perimeter prediction would have shown that two zones were not needed, though the men would have been ordered. This would have an overhead cost saving of about $40,000 to $50,000.

Gene Murphy ordered a firing operation on the north ridge (Vista Grande to Angeles) which was under CDF responsibility. However, because of poor communication and coordination, the order was not carried out. Better communication and coordination would have eliminated this confusion, saving an additional 2,000 acres.

It was also pointed out that two separate teams of 60 handcrews were ordered by CDF and USFS for the same purpose. Under improved communication and coordination this could have been avoided. An on-site resource inventory function would have allowed for the more efficient use of resources. It was estimated that both these functions would have reduced suppression costs by about 10 percent.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Backfire Indian Truck Trail	No change.
Order resources at 4:30 pm	With better organizational setup the men would have been ordered earlier. Early arrival would have saved 1,500 acres.
Do not fire out Banning-Idylwild Highway	A formalized prediction system probably would have reversed this decision. Complete control would not have been achieved but an expected reduction of 5,500 acres could have been achieved.
Protect south flank with maximum emphasis	Emphasis could have been reduced if accurate perimeter prediction had been available.
Divide the fire into two zones	If it had been predicted that the fire would not hit the south flank head-on, overhead costs of an extra zone could have been eliminated, saving $40,000 to $50,000 in 1974 dollars.

e. Calculation of FIRESCOPE Savings

Because of the diversity of land-use in the burn area, average values per burned acre are particularly misleading for the Soboba fire. The Forest Service reported the following damages for the fire (in 1974 dollars): timber--$3,940,000; watershed--$3,649,000; other resources--$2,400,000. The average damage per acre, exclusive of timber damage, was $342. There was no timber in the Angeles area and fire officials indicated that the acreage in that area was worth less than the average acreage in the fire, and so we assign a total value of $300 per acre to the Angeles area. The average value of watershed for the entire fire was $206 per acre, but since the burn area above the Banning-Idylwild Highway was significantly steeper than the rest of the fire, we assign a watershed value to that area of $300 per acre. We also assume that about 65 percent of the timber damage and 50 percent of the other resources damage occurred in the area above the Banning-Idylwild Highway.

Improvements in the organizational structure, and communications and coordination would have allowed for saving 3,000 acres in the Angeles area, or $615,000 in 1970 dollars. Improved communication and coordination would have also allowed for a 10-percent savings in suppression costs. A simple computerized prediction system would have enabled an expected savings of 5,500 acres above the Banning-Idylwild Highway, or $3,833,000 in 1970 dollars. An additional reduction in suppression costs of $164,000 would have occured there because of the acreage saved. Perfect information on fire conditions would have shown that two zones were not needed, allowing for an additional savings in suppression costs of $30,000 in 1970 dollars.

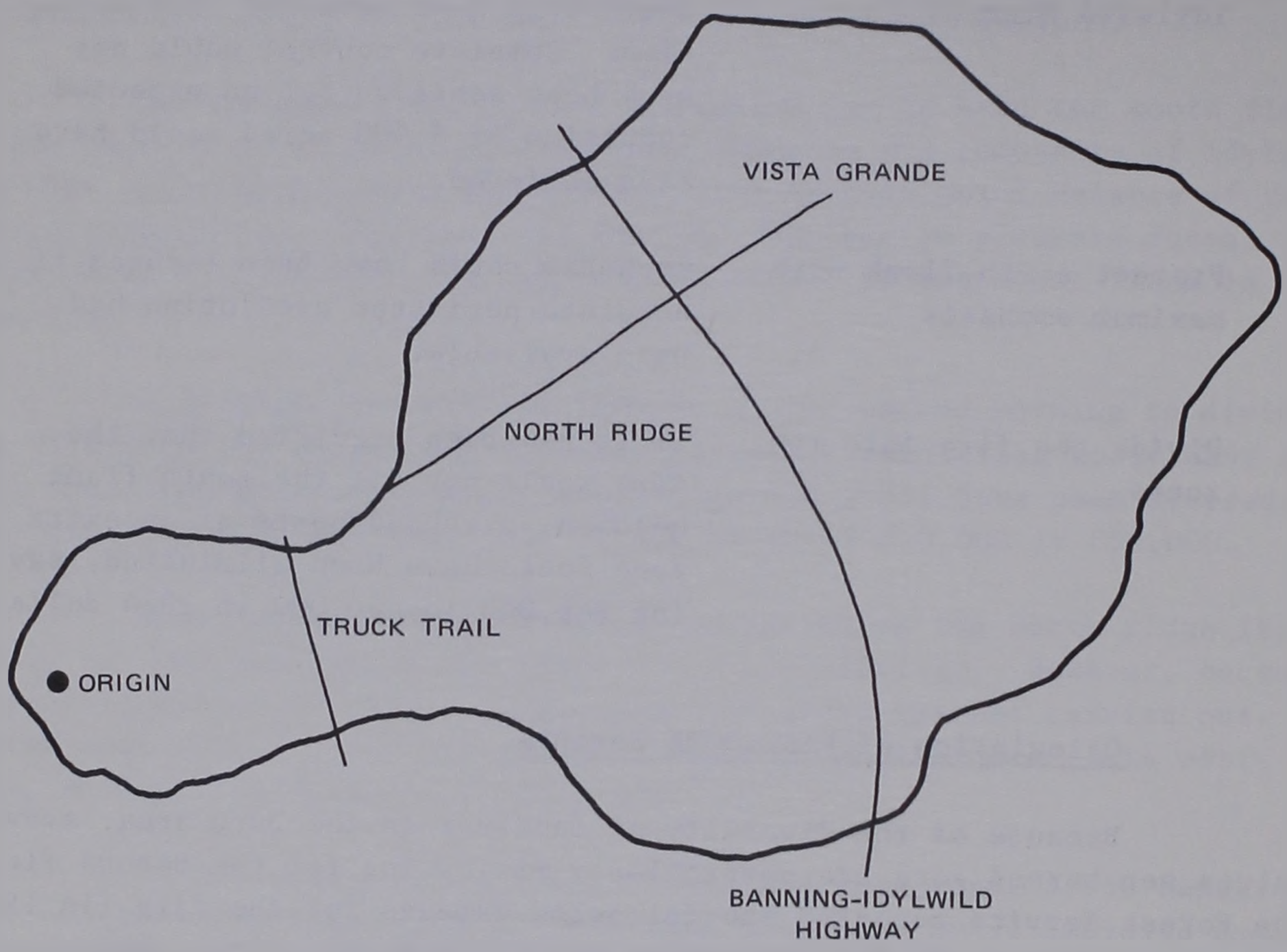

FIGURE A-6 SIMPLIFIED MAP OF SOBOBA FIRE

Table A-7

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON SOBOBA FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the Time of the Fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling: • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	17,683	14,683	14,683	9,183	9,183	9,183	9,183
Houses	--	--	--	--	--	--	--
Damage (dollars)							
Acreage	$6,808,000	$6,193,000	$6,193,000	$2,360,000	$2,360,000	$2,360,000	$2,360,000
Houses	--	--	--	--	--	--	--
Suppression cost (dollars)	1,640,000	1,476,000	1,476,000	1,312,000	1,312,000	1,312,000	1,282,000
Total cost plus loss (dollars)	$8,448,000	$7,669,000	$7,669,000	$3,672,000	$3,672,000	$3,672,000	$3,642,000

8. Bear Fire, San Bernardino National Forest, November 11-19, 1970. Based on discussions with Gene Kemble (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	heavy brush
Terrain:	steep
Acreage burned:	53,100 acres
Houses destroyed:	49 cabins (10 equivalent houses)
Suppression costs:	$1,800,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$360	Administrative Review
Other ($/acre)	65	SRI
Total	$425	
Structural-related losses:	$53,600 per effective house	

c. Fire Narrative

The Bear fire was started by a hiker-fisherman who left a warming fire in North Fork of Bear Creek, more than a mile away from the nearest trail in very difficult terrain.

The fire was discovered on November 13, 1970, at 3:00 am by the Butler Peak Lookout. Initial attack personnel arrived 30 minutes after it was reported. Due to its location, the fire was not visible to ground units until 45 minutes later. Very steep terrain, heavy brush, and hurricane-like winds made it impossible to send men down the hill to the fire.

Though the initial plan was direct attack, consideration for the safety of personnel changed the decision, and the men were withdrawn from that area and assigned to the flanks. The availability of FIRESCOPE would not have affected this decision.

At 4:20 am the fire began to spread upslope to the northeast, and it reached Glory Ridge at 5:30 am. At this time, the suppression crews started an unsuccessful flanking action on the north edge.

At 5:10 am the fire spotted one-half mile southwest of the main fire about halfway up the ridge running from Lake View Point to the North Fork of Bear Creek. At that time the fire was being driven by the full force of 100 mph Santa Ana winds.

At 6:00 am an order for two zones and 40 pumpers was placed. Due to the smoky nature of the fire, air attack was not possible. The only action possible was a flanking attack.

The fire was burning at a rate of one acre per second and by 12:00 noon it was 25,000 acres in size. Since three residential communities (Smiley Park, Running Springs, and Arrowhead) on the northwest were in danger, an additional order for 60 pumpers was made. At 10:00 am, Zone 1 fire boss Kemble thought the fire would arrive at the residential areas in the afternoon (3:00 to 5:00 pm). Kemble did not order sprinkler systems for those areas because he felt there was not enough time. However, if a prediction system had predicted that the fire would arrive at the residential areas around 10:00 pm when it actually did, then Kemble maintains that he would have ordered the sprinkler system. Kemble maintains that with 40 pumpers and a sprinkler system it would have been possible to save almost all the cabins that were lost.

The decision was made to protect Camp Angeles with low-level support (6 to 8 pumpers) and it turned out to be outside of the burn perimeter.

Kemble feels that improved communication and coordination and resource inventory would have helped in the effective use of the pumpers that were placed in the communities. These additional resources could have helped in flanking activities and also in firing out Highway 30.

A backfiring operation along the Alder Creek Road was effective and stopped the spread along the south. This was possible because of favorable local wind conditions.

A backfiring effort along Highway 30 was unsuccessful because of insufficient resources. Kemble feels that improved communication and coordination and resource inventory control could have located sufficient resources, and given them a 50-percent chance of saving 2,000 acres.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Withdraw initial attack forces	No impact.
Order 2 zones and 40 trucks at 6:00 am.	Decision was made on complete guesswork. FIRESCOPE could provide direction and more accurate prediction of needs.
Defend Smiley Park, Running Springs, and Arrowhead	A formal perimeter prediction system would have shown that there was time to order more resources. Savings of up to 49 cabins could have been realized.
Fire out Highway 30	Improved communication and coordination and resource inventory control would have located additional resources, enabling an expected savings of 1,000 acres.

c. Calculation of FIRESCOPE Savings

Improved communication and coordination, and resource inventory control would have given a 50-percent chance of saving 2,000 acres at Highway 30.

We assume that it would have taken 8 hours and an additional $20,000 to mobilize the additional suppression effort for the residential areas, and that the incident commander would have decided to undertake the additional effort if the predicted time of fire arrival was more than 8 hours. It actually took 12 hours for the fire to arrive there. From our definition of an $\alpha = 1/2$ prediction system, the predicted time of fire arrival under that system would have been normally distributed, with mean 12 hours and standard deviation 3 hours. The probability of the predicted time of fire arrival being under 8 hours would have been:

$$P(\text{predicted arrival time} < 8) = 1 - N\left(\frac{8 - 12}{3}\right)$$

$$= 1 - 0.91$$

$$= 0.09 \quad .$$

Thus, there would have been a 91-percent chance of deciding to order more resources. Assuming an 80-percent chance of success for the additional suppression effort, an expected savings in housing losses of about 73 percent would have occurred under an $\alpha = 1/2$ prediction system:

$$0.8 \times 0.91 = 0.73 \quad .$$

The expected additional suppression costs for this effort would have been:

$$0.91 \times \$20,000 = \$18,200 \quad .$$

Similarly, under an $\alpha = 1/3$ prediction, there would have been a 97.5-percent chance of ordering the additional resources. This would have given expected savings of $0.8 \times 0.975 = 78$ percent of the houses, and would have increased expressed suppression costs by $0.975 \times 20,000 = \$19,500$.

Under an $\alpha = 1/6$ prediction system, the prediction would have indicated sufficient time to order the resources with nearly 100-percent probability. Thus, there would have been expected housing savings of $1.00 \times 0.8 = 80$ percent, and additional expected suppression costs of $1.00 \times \$20,000 = \$20,000$.

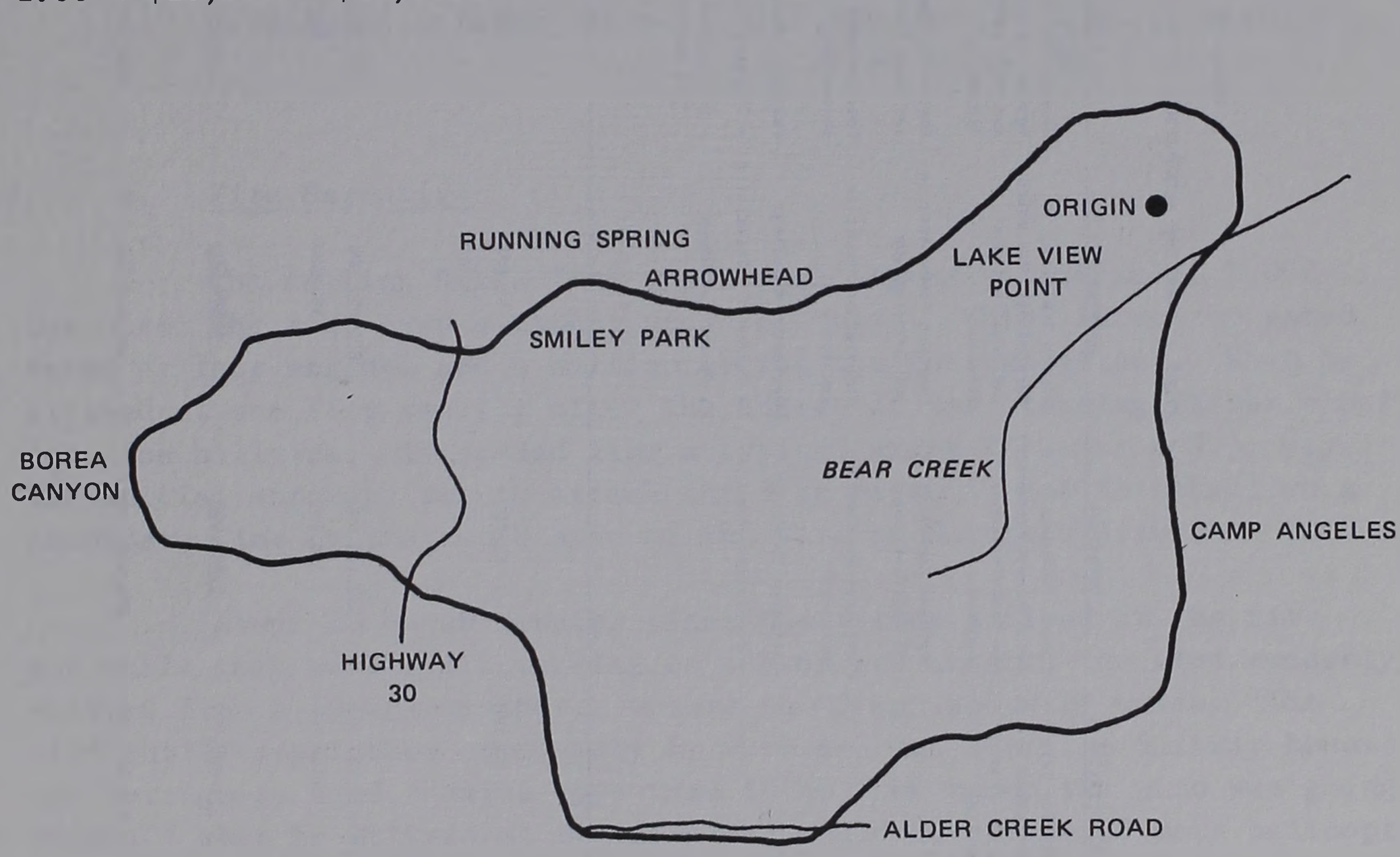

FIGURE A-7 SIMPLIFIED MAP OF BEAR FIRE, SAN BERNARDINO NATIONAL FOREST

Table A-8

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON BEAR FIRE, SAN BERNARDINO NATIONAL FOREST

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the Time of the Fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling: • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	53,100	52,100	52,100	52,100	52,100	52,100
Houses	10	10	10	2.7	2.2	2
Damage (dollars)						
Acreage	$22,567,500	$22,142,500	$22,142,500	$22,142,500	$22,142,500	$22,142,500
Houses	536,000	536,000	536,000	144,720	117,920	107,200
Suppression cost (dollars)	1,800,000	1,800,000	1,800,000	1,818,200	1,819,500	1,820,000
Total cost plus loss (dollars)	$24,903,500	$24,478,500	$24,478,500	$24,105,420	$24,079,920	$24,069,700

9. Rolling Hills Fire, June 22, 1973. Based on discussions with Paul Snyder and Robert Sarno (LACoFD).

a. General Conditions

Weather:	strong winds after escape
Fuel:	heavy grass
Terrain:	rolling hills
Acreage burned:	897 acres
Houses destroyed:	12
Suppresssion costs:	$125,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$250	Russ Stallings
Other ($/acre)	65	Stallings/SRI
Total	$315	
Structural-related losses:	$201,000 per destroyed house	Robert Sarno/ SRI

c. Fire Narrative

The Rolling Hills fire started in a grassy plot about 2,000 feet from the road down a rather steep hillside. Chief Sarno requested three or four engines and a helicopter for the initial attack. When he arrived at the fire shortly after the start, it was creeping rather slowly down the hillside. It seemed like a typical grass fire for a June day. The initial strategy was to attack the fire directly and to establish a secondary line on the south side of the fire at Narcissa Drive.

About 20 to 30 minutes after the forces arrived at the fire and while they were still working on the direct attack, the wind suddenly shifted from a 10 mph northerly breeze to 40 mph westerly winds. The wind shift caught them completely by surprise and the fire quickly headed for Portuguese Bend. Sarno says that if he had known the wind was going to shift when he arrived at the fire, he would have ordered more helicopters and changed his attack, and he is sure that he could have contained the fire before it got into the housing areas. An amateur meteorologist who had lived in the area for many years claims that the shift was not at all typical for June and could not have been predicted.

The wind was just shifting when Division Assistant Chief Paul Snyder arrived at the fire. He quickly ordered 10 more engines and had them dispatched to Portuguese Bend. It took up to 45 minutes for these engines to arrive. By the time they arrived, numerous calls were being received claiming that the fire had entered the Oceanaire area. The fire was very smoky and brands were being blown around. Even though it appeared to the residents that the fire was in Oceanaire, the main part of the fire never arrived there; but because of the reports, the 10 engines were diverted from Portuguese Bend to Oceanaire.

Snyder estimated that if the calls had not been received and if infrared photos had been available showing where the fire was, perhaps only three engines would have been diverted to Oceanaire, resulting in a 50-percent savings in the Portuguese Bend area. He doubted that he could have ignored the calls, even if he had had infrared photos; but perhaps he could have kept two or three engines at Portuguese Bend if he had both infrared photos and the erroneous residential calls.

Six more engines were ordered from LA City. They were originally intended for Portuguese Bend, but were diverted to Southfield to set up a secondary line there. The fire entered the Portuguese Bend area and Chief Snyder decided that he wanted the LA City forces back in Portuguese Bend. It took over an hour to get them because of interagency communication problems. Snyder now estimates that they could have saved 20 percent of the houses if there had not been the communication problems.

The wind died down about four hours after the start of the fire, and the fire was contained at 897 acres, with 12 homes totally destroyed. Chief Sarno is quite certain that the losses could have been eliminated if they had known in advanced that the winds were going to shift. On the other hand, if they had been given a correct perimeter prediction immediately following the wind shift, there would have been a small chance of containing the fire before it escaped into the residential area.

Sarno also said that if it had taken more than an hour for FIRESCOPE to make its prediction, it would have been too late to make any difference on the losses. He also pointed out that a wrong prediction would have been disastrous because they would have moved their resources away from the Portuguese Bend area, where they were actually needed.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Order resources for initial direct attack	If the wind shift had been predicted, then substantially more resources would have been ordered and the fire would have been contained at 10 to 15 acres.
Establish secondary lines at Narcissa and Portuguese Bend	Basic decision would not have changed, but reliable perimeter prediction would have caused reinforcement of Portuguese Bend effort, reducing housing losses by 20 to 30 percent.
Divert resources from Portuguese Bend to Oceanaire	Infrared photos in absence of erroneous phone calls would have kept 7 of 10 trucks at Portuguese Bend, reducing housing losses by 50 percent (includes above 20 to 30 percent). So long as there were erroneous phone calls it is doubtful that diversion would have been changed even if the infrared photos had been available.
Divert resources from Southfield to Portuguese Bend	Improved coordination would have greatly hastened this effort, saving about one-third of the losses (included in above 50 percent).

e. Calculation of FIRESCOPE Savings

Improved communication and coordination would have allowed for more effective resource utilization at Portuguese Bend, saving four houses. Possibly two more houses could have been saved if a formal computerized prediction had been available at the time of the wind shift, indicating the immediate threat to Portuguese Bend. Such a prediction would have hastened the establishment of a secondary line on Portuguese Bend, allowing for saving the two houses.

To evaluate the benefit of a formal prediction system, we will assume that the Portuguese Bend secondary defense effort would have been singificantly increased if a formal prediction had been available at the

time of the wind shift saying that the fire would be in Portuguese Bend in 90 minutes or less. In fact, it took 60 minutes for the fire to reach there. From the definition of an $\alpha = 1/2$ system, the predicted time of arrival under an $\alpha = 1/2$ prediction system would have been normally distributed, with mean 60 minutes and standard deviation 15 minutes. The probability of the predicted time of arrival being less than 90 minutes would have been:

$$P(\text{predicted arrival time} < 90) = N\left(\frac{90 - 60}{15}\right)$$

$$= 0.977 \quad .$$

Thus, under an $\alpha = 1/2$ prediction system there would have been a 97.7-percent chance of saving two additional houses, giving expected additional savings of $0.977 \times 2 \times \$201,000 = \$392,000$.

Similar calculations show that the predicted time of arrival under an $\alpha = 1/3$ and $\alpha = 1/6$ system would have been under 90 minutes with probability 0.999, and so we assign additional savings of two houses to those alternatives.

After the wind shift occurred, perfect information on the fire conditions would have given a 5-percent chance of containing the entire fire. The expected savings for this case would be 44 acres and 6.3 houses [$(0.05 \times 12) + (0.95 \times 6) = 6.3$]. Expected suppression costs would have been reduced by the same 5 percent.

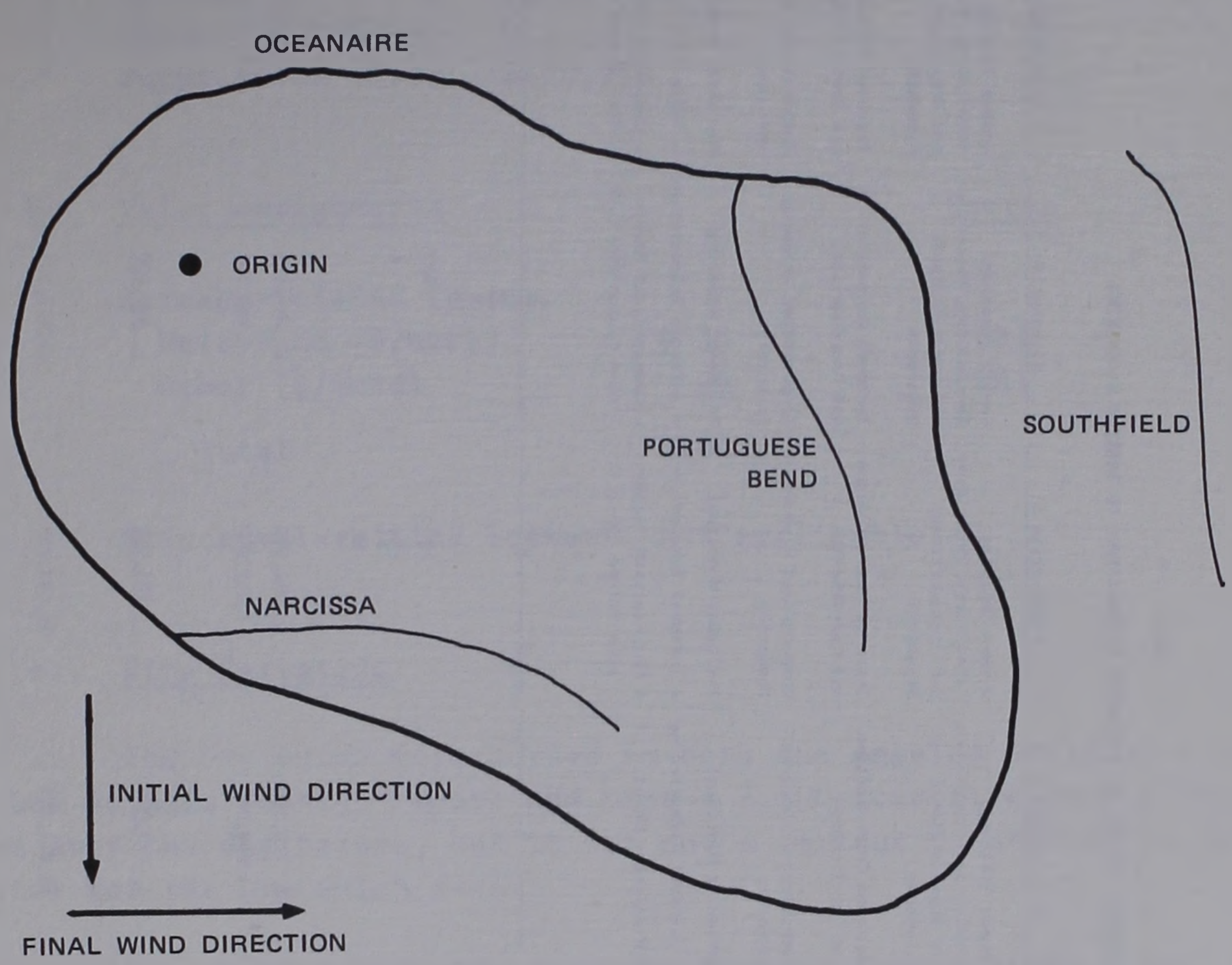

FIGURE A-8 SIMPLIFIED MAP OF ROLLING HILLS FIRE

Table A-9

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON ROLLING HILLS FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering • Prediction Wheel	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	• Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	897	897	897	897	897	853
Houses	12	8	8	6.1	6	5.7
Damage (dollars)						
Acreage	$ 282,555	$ 282,555	$ 282,555	$ 282,555	$ 282,555	$ 268,695
Houses	2,412,000	1,608,000	1,608,000	1,215,200	1,206,000	1,145,700
Suppression cost (dollars)	125,000	125,000	125,000	125,000	125,000	118,750
Total cost plus loss (dollars)	$2,819,555	$2,015,555	$2,015,555	$1,622,755	$1,613,555	$1,613,555	$1,533,145

10. Dry Gulch Fire, September 22, 1974. Based on discussions with Paul Snyder and Robert Sarno (LACoFD); Richard Montague (USFS).

a. General Conditions

Weather:	hot, 25 mph wind, SW
Fuel:	20 to 30-year-old brush
Terrain:	rolling
Acreage burned:	5,800 acres
Houses destroyed:	0
Suppression costs:	$170,750

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$ 35	SRI
Other ($/acre)	65	SRI
Total	$100	
Structural-related losses:	not applicable	

c. Fire Narrative

The Dry Gulch fire burned in both the Angeles National Forest and Los Angeles County. There had been a 3,500-acre fire only a few miles away the day before, but it was not a serious constraint on resources for the Dry Gulch fire.

The area of the main burn was largely inaccessible. The strategy was to flank it via direct attack at the origin and along Lake Hughes Road. Tapia Canyon fire road was backfired to stop the front of the fire. At the time the backfiring started, Chief Swallow estimated that it would take three hours for the fire to reach the fire road and that it would take one-half hour to fire it out. His estimates were correct and the fire was extinguished when it hit the backfire.

It appears that FIRESCOPE would have been of little assistance in this fire. Because of the limited access to interior portion of the burn area, it would have been difficult to reduce the perimeter. There were no other major fires burning in the region, and so there were no problems of resource management.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Direct attack on the flanks	No effect.
Backfire Tapia Canyon Fire Road	No effect.

e. Calculation of FIRESCOPE Savings

No savings would have occurred.

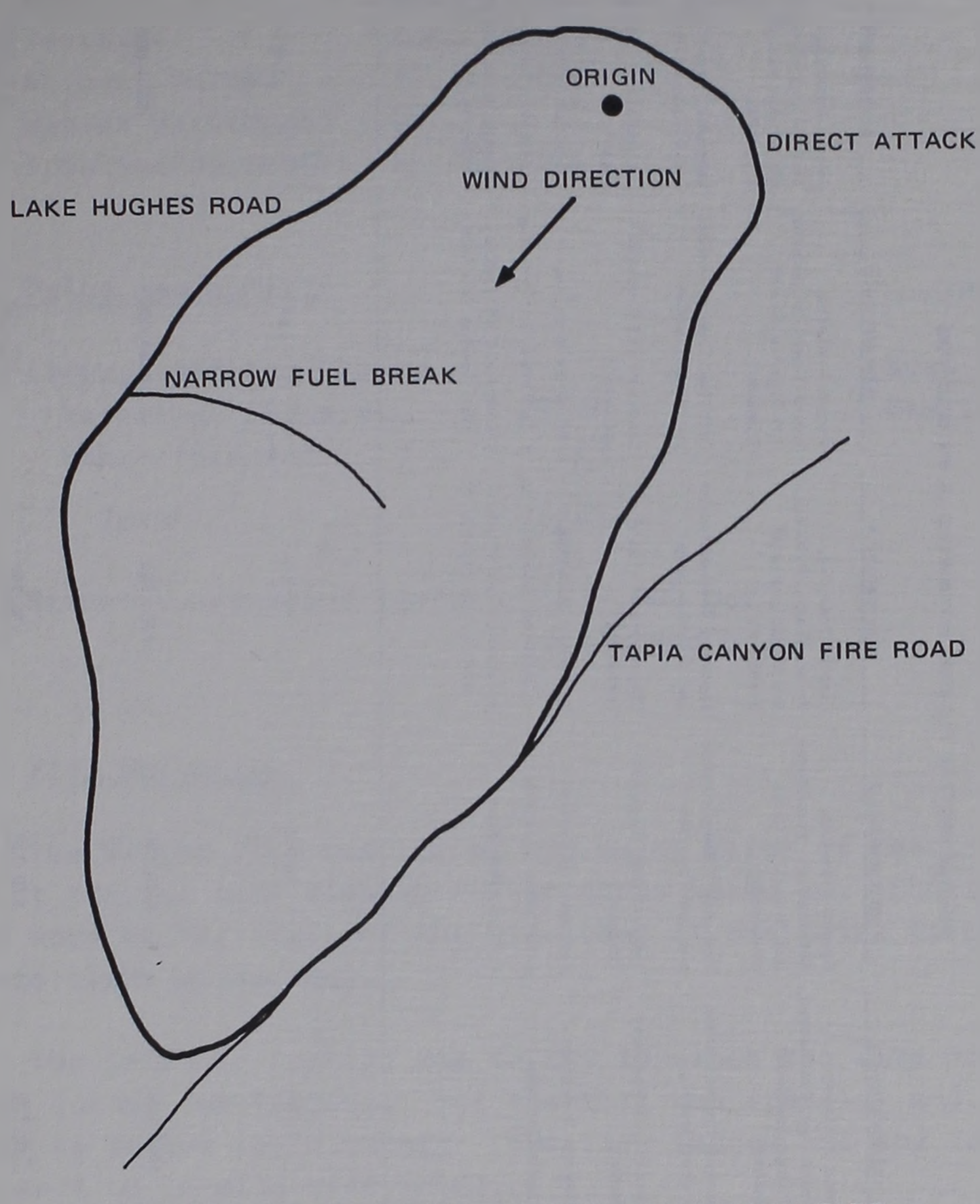

FIGURE A-9 SIMPLIFIED MAP OF DRY GULCH FIRE

Table A-10

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON DRY GULCH FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling: • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	5,800	5,800	5,800	5,800	5,800	5,800
Houses	--	--	--	--	--	--
Damage (dollars)						
Acreage	$580,000	$580,000	$580,000	$580,000	$580,000	$580,000
Houses	--	--	--	--	--	--
Suppression cost (dollars)	170,750	170,750	170,750	170,750	170,750	170,750
Total cost plus loss (dollars)	$750,750	$750,750	$750,750	$750,750	$750,750	$750,750

11. Wright Fire, September 25-27, 1970. Based on discussions with Ben Matthews and Russ Stallings (LACoFD).

a. General Conditions

Weather:	severe fire weather
Fuel:	mixed brush and grass
Terrain:	rolling hills
Acreage burned:	27,925 acres
Houses destroyed:	103
Suppression costs:	$1,250,000

b. Value Assignments

		Source
Acreage-related losses		Russ Stallings
Watershed ($/acre)	$200	Stallings/SRI
Other ($/acre)	65	
Total	$265	
Structural-related losses:	$134,000 per destroyed house	

c. Fire Narrative

The Wright fire was one of the major fires of the 1970 fire season. It started near Highway 101 at about 10:00 am. Chief Matthews says they knew at the start of the fire that it was going to go to the ocean, some eight miles away.

The initial strategy was to try to pinch the fire off and contain it to one or two canyons. But the fire was spotting and it was impossible to follow the strategy. The fire fanned out and reached the ocean on an 8 to 10-mile-wide front.

Once it became evident that the perimeter could not be contained, the strategy changed from perimeter control to structural protection. About 20 engines were committed to the upper part of Malibu Canyon. They were generally successful in defending the structures there. Once the fire passed through the area, the engines stayed in the area protecting some of the adjacent communities that had not been burned during the initial run of the fire. As it turned out, these

engines were not heavily involved in the rest of the fire. They were not requested at the beachfront because there were already too many engines there to manage. In retrospect, they could have been directed to another fire, such as the Clampitt Fire. But even if the Clampitt boss had requested those resources, Matthews doubts that he could have released more than five to ten of the engines because of the continued threat to the upper Malibu area.

The fire reached the beachfront late in the afternoon. Visibility was less than 400 feet because of the smoke. Given the speed with which the fire developed, Matthews feels that their organization was quite good. He felt that a top-level organization might have allowed him to save 20 to 30 percent of the losses in that area. He doubts that such an organization could ever be developed in our time, but feels that a well-functioning FIRESCOPE system would have allowed him to reduce the losses by 10 to 15 percent through better organization. Some houses were lost because some of the trucks were immobile because of fixed hose lays. He feels that FIRESCOPE training would have eliminated this problem.

In general, Matthews felt that he had adequate resources for the fire. There was little that could have been done to reduce the perimeter. The major problem on the fire was that the resources were not used as effectively as possible in the Malibu Beach area. This was primarily because of the smoke, intensity of the fire, lack of training, and inadequate organization for the size of effort involved.

In subsequent discussions of the fire, Matthews felt that an improved organization and resource inventory control would have enabled them to save 20 percent of the burned acreage through improved control of the flanks.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Initial flanking action.	No effect.
Concentration on structural protection instead of perimeter control in upper Malibu area.	No effect.
Structural protection in Malibu Beach area	Basic decision would not have changed. Improved organization and training through FIRESCOPE could have cut housing losses by 7 to 10 houses.

e. Calculation of FIRESCOPE Savings

Improved communication and coordination, resource inventory control, and organizational structure would have allowed for a 20-percent savings in acreage burned and a savings of 10 houses in the Malibu Beach area. To achieve these savings it would have been necessary to increase suppression expenditures by 20 percent because of the added effort needed.

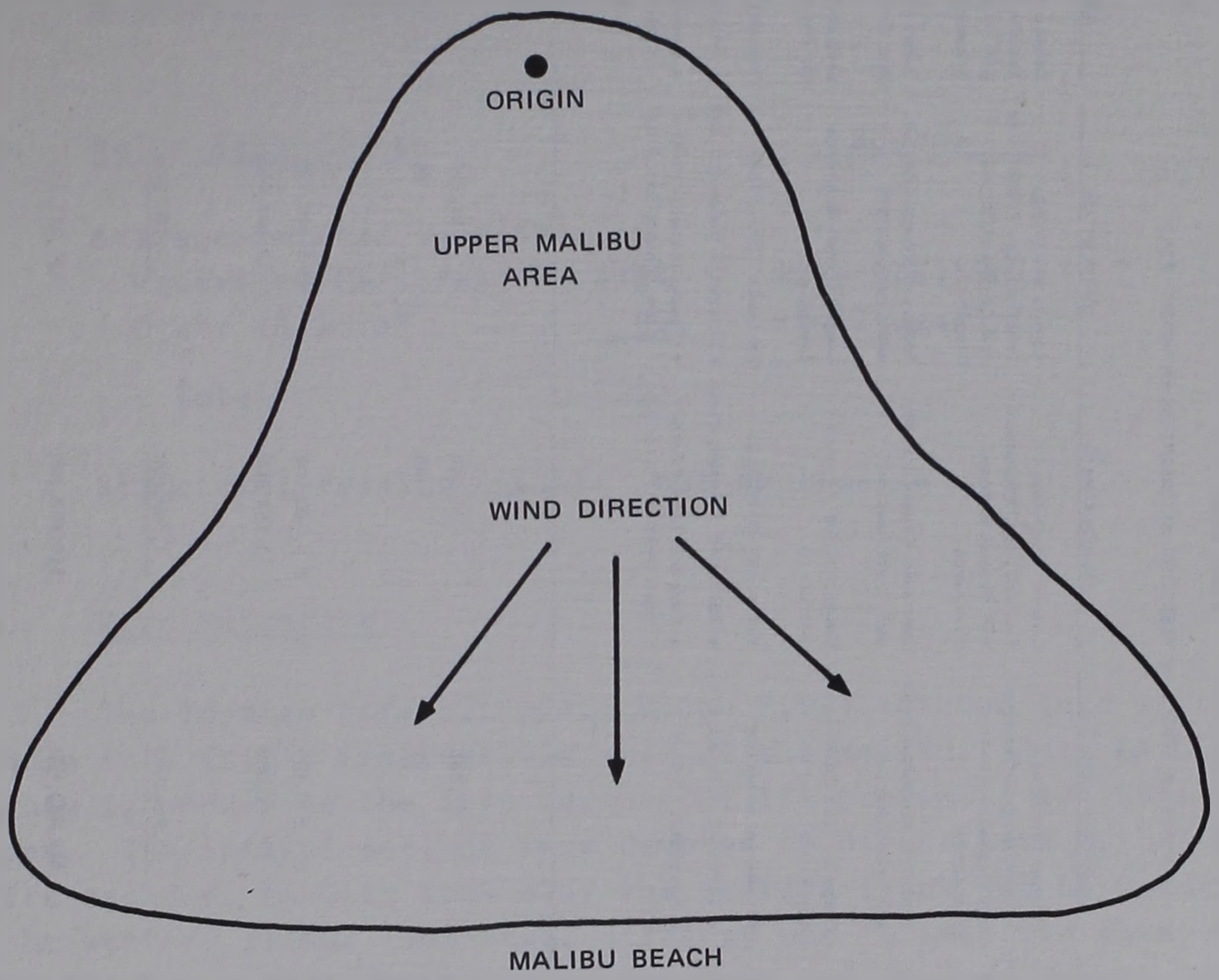

FIGURE A-10 SIMPLIFIED MAP OF WRIGHT FIRE

Table A-11

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON WRIGHT FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling: • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	27,925	22,340	22,340	22,340	22,340	22,340
Houses	103	93	93	93	93	93
Damage (dollars)						
Acreage	$ 7,400,125	$ 5,920,100	$ 5,920,100	$ 5,920,100	$ 5,920,100	$ 5,920,100
Houses	13,802,000	12,462,000	12,462,000	12,462,000	12,462,000	12,462,000
Suppression cost (dollars)	1,250,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Total cost plus loss (dollars)	$22,452,125	$19,882,100	$19,882,100	$19,882,100	$19,882,100	$19,882,100

12. Topanga Fire, October 30-31, 1973. Based on discussions with Ben Matthews (LACoFD).

a. General Conditions

Weather:	severe fire weather
Fuel:	heavy brush
Terrain:	steep
Acreage burned:	1,700 acres
Houses destroyed:	0
Suppression costs:	$94,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$185	Russ Stallings
Other ($/acre)	65	Stallings/SRI
Total	$250	

Structural-related losses: not applicable

c. Fire Narrative

The Topanga Fire (Trippett Ranch Fire) started late in the afternoon in a fairly inaccessible area of the Malibu. Both LA City and LA County responded to the fire because of its proximity to their jurisdictions. The initial actions were devoted to direct attack, but when the fire escaped, LA City took over the eastern flank and LA County took over the western flank. The basic strategy was to keep the fire contained between the Santa Ynez fuelbreak on the east and Topanga Canyon Boulevard on the west.

The wind was gusty and continually changing direction. At 8:00 pm it appeared that the fire was headed for Fernwood, and the order was made to evacuate the town. Fortunately, the fire bypassed Fernwood, due in part to suppression efforts, but also due to the wind and terrain.

The fire crossed Topanga Canyon Boulevard at about 10:00 pm and went into Tuna Canyon. It burned about 400 acres in Tuna Canyon. Matthews says that he wanted to fire out the part of Topanga Canyon Boulevard where the fire crossed but was convinced not to because of the late hour of the decision and inherent danger of backfiring. In retrospect, he now says

that if he had been given a rate-of-spread prediction early in the course of the fire, he probably would have elected to undertake the firing operation. He said there was an 80-percent chance that the line would have held, saving 400 acres.

The fire threatened Pacific Palisades on the eastern side of the fire. It hit that area very hard, but there were adequate resources and brush clearance to protect the area. No houses were burned. Although at times it appeared that there were too many resources on the fire, Matthews says that they were all needed, given the threat to Fernwood and Pacific Palisades. There was also a continued threat of the wind shifting direction and blowing the fire back uphill, and the resources were needed to cover this contingency.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Keep the fire between Topanga Canyon Boulevard and Santa Ynez fuelbreak.	No effect.
Do not fire out lower-middle portion of Topanga Canyon Boulevard.	An early prediction on perimeter would have reversed this decision giving an 80-percent chance of saving 400 acres.
Order sufficient resources for defense of Fernwood and Pacific Palisades.	No effect.

e. Calculation of FIRESCOPE Savings

An approved organizational structure would have allowed the incident commander to consider the long-term strategy possibilities earlier than he did. Under these circumstances he would have elected to backfire Topanga Canyon Boulevard earlier than he actually did, giving an 80-percent chance of saving 400 acres. Perfect information on fire conditions would have allowed a 10-percent reduction in suppression costs, because of a reduced effort at Fernwood and Pacific Palisades.

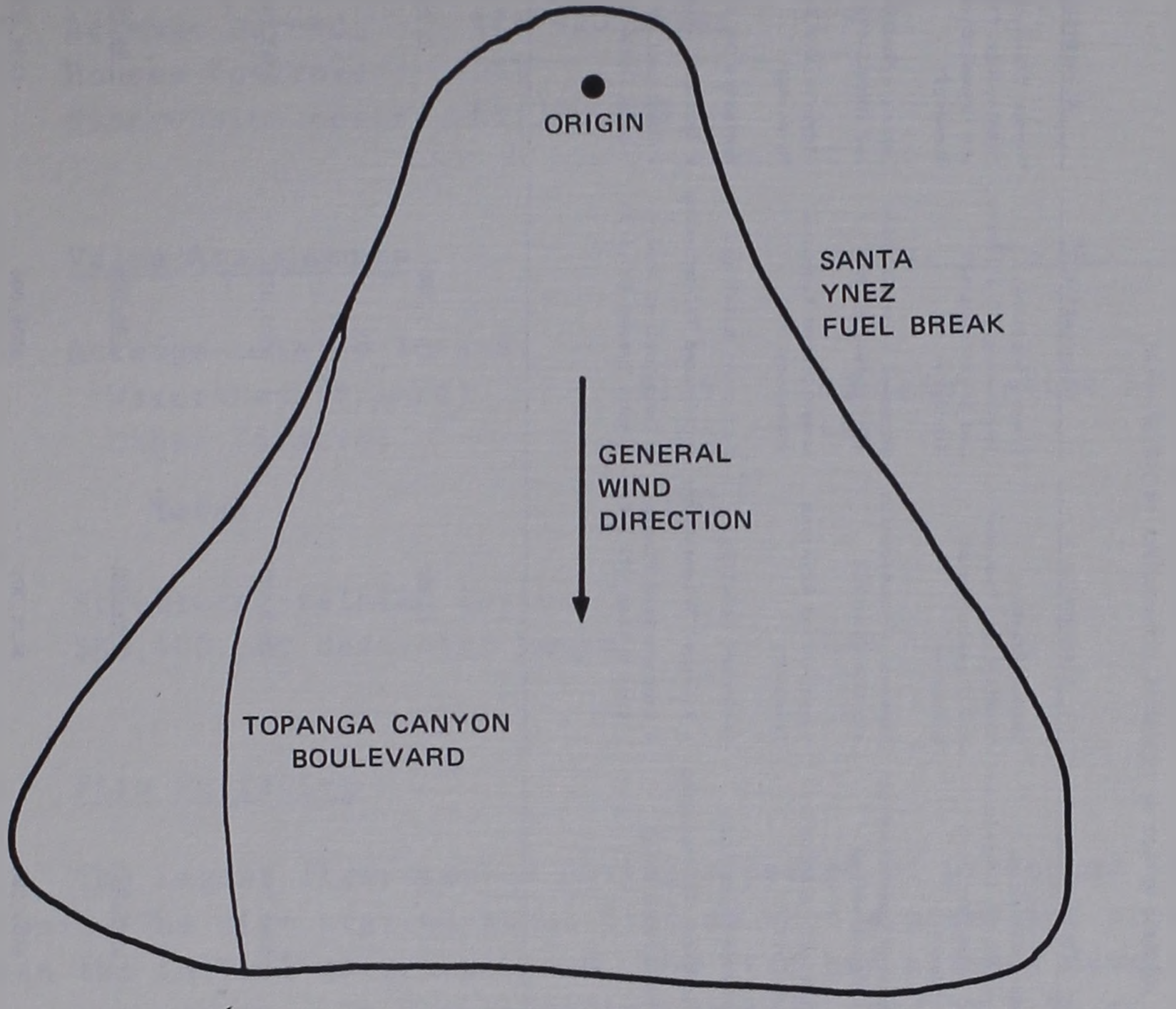

FIGURE A-11 SIMPLIFIED MAP OF TOPANGA FIRE

Table A-12

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON TOPANGA FIRE

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
		Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
		Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
		Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
		• Prediction Wheel	• Infrared Telemetering • Prediction Wheel	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	• Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	• Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses							
Acreage	1,700	1,380	1,380	1,380	1,380	1,380	1,380
Houses	--	--	--	--	--	--	--
Damage (dollars)							
Acreage	$425,000	$345,000	$345,000	$345,000	$345,000	$345,000	$345,000
Houses	--	--	--	--	--	--	
Suppression cost (dollars)	94,000	94,000	94,000	94,000	94,000	94,000	84,600
Total cost plus loss (dollars)	$519,000	$439,000	$439,000	$439,000	$439,000	$439,000	$429,600

13. Laguna Fire, September 26-30, 1970. Based on discussions with Myron Lee (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	mixed timber, brush, and grass
Terrain:	steep to rolling hills
Acreage burned:	175,420 acres
Houses destroyed:	382
Suppression costs:	$1,500,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$125	Administrative Review
Other ($/acre)	65	SRI
Total	$190	
Structural-related losses:		
$80,400 per destroyed house		Lee/SRI

c. Fire Narrative

The Laguna fire started during a period of prolonged Santa Ana conditions. The fire started about 6:15 am when a powerline broke. By 6:30 when the initial attack arrived, the fire had already developed three separate spots. It was spreading rapidly, and by 7:00 am the order was issued to prepare for a project fire.

The initial strategy was to try to contain the fire at Sunrise Highway on the north and at Interstate 8 on the west. Although there was some delay in obtaining the necessary resources because of other major fires in the region, Myron Lee feels that they could not have effectively used any more resources than they actually had. The fire was spotting and burning intensely and it would have been too risky to commit more resources to the lines than they actually did. Lee claims that not even the 6th Army could have held the fire at Interstate 8.

The fire crossed Interstate 8 at about 10:00 am burning in a southwesterly direction. Once it crossed Interstate 8, there was nothing but miles of brush in front of the fire.

Once the fire crossed Interstate 8, the strategy changed from perimeter control to the protection of property and life. Additional resources were sent into Pine Valley where there were 400 homes. At the peak of the threat, 50 engines were in Pine Valley. Four houses were lost there.

The weather forecast for that day was for decreasing Santa Anas. Myron also said that it was almost certain that the winds would shift from northeast to east by the afternoon. Based on this forecast, DFCO Raybould predicted that the fire would reach the Japatul area (some 20 miles away) by 10:00 am the next day and would be 40,000 acres in size. He made this prediction at 10:00 am the first day, three-and-one-half hours after the start of the fire. This prediction shows that they recognized that the fire was going to change direction toward the general San Diego area and that the fire was going to travel at an extremely fast rate of spread. Raybould also predicted that the fire would not be controlled by 10:00 am the next day.

As soon as the prediction was made, secondary lines were ordered for Harbison Canyon, Suncrest, and some of the other areas outside San Diego.

The winds never diminished the first day or night and the fire reached the Japatul area by 2:00 am instead of 10:00 am as predicted. Lee feels that there was only a slight chance of the fire being held at Japatul Road even if they had intensified their effort at that point because of a perimeter prediction. They had already started evacuation of Harbison Canyon and all the firemen could do was to wait for the fire, and so he doubts that an earlier warning would have changed the strategy much.

The fire burned into several urban areas and there were heavy losses. Lee feels that there were adequate resources for the structural defense effort. In fact, he said they had to pull resources out of Harbison Canyon for reasons of safety. He attributes the housing losses to the extreme intensity of the fire, poor hazard reduction, wooden roofs, and narrow, dead-end streets. He said there were not any significant communication or coordination problems that hampered the defensive effort. The Harbison Canyon losses were not a result of not knowing where the equipment or fire was; they were the result of an intensive fire burning through an urban area with significant fire hazards.

There were instances during the fire when incorrect reports were given about the fire location. If these could have been avoided, perhaps

by having good infrared photos, the suppression costs could have been reduced by perhaps 10 percent. But the perimeter probably would not have been affected.

Subsequent to our discussions with Myron Lee, we spoke with Frank Crossfield about the Laguna fire. He was the CDF district ranger in charge of the San Diego area at that time and was in charge of much of the structural protection effort on the fire. He confirmed Myron Lee's assessment of the Harbison Canyon losses: given the intensity of the fire that passed through Harbison Canyon, the housing losses were inevitable. The canyon was narrow; hazard reduction was poor; and once the fire entered the canyon, there was little additional effort that the firemen could have made to have reduced losses.

The Suncrest area lost about 100 structures. Crossfield feels that if they had had more equipment, they could have cut the losses in that area by perhaps 25 percent. He requested more resources for anticipated structural protection on the first afternoon, but was told that no more resources were available. Other major fires were being fought at the same time in the Los Angeles area. When it became evident on the second day that Suncrest was going to be hit, additional resources were finally moved in. Crossfield feels that an accurate perimeter prediction on the first day of the fire would have helped his case in trying to obtain the additional resources when he originally requested them. He is not sure that they would have been sent any earlier because they were being used in Los Angeles, but at least there would have been a more informed basis for making the resource allocation decision among the different fires.

Raybould's prediction on 10:00 am of the first day shows that they knew the fire was going to approach the general San Diego area. There were many communities on the outskirts of San Diego that could have been threatened, depending on the actual perimeter of the fire when it finally hit the urban area. Crossfield said they knew that Harbison Canyon and Suncrest were vulnerable areas, but it was not until there was a slight shift in the wind direction the second morning of the fire that they really knew the fire was going to enter Harbison Canyon. If there had not been that slight wind shift, the head of the fire might have missed Harbison Canyon and Suncrest, but then it might have burned into some other communities. Crossfield doubts that anyone could have predicted the subtle shift early enough to have had any effect on the losses.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Initial perimeter control of Sunrise Highway and I-8	No effect.
Order all available resources for major project fire	Credible perimeter prediction would have emphasized urgency of request and might have enabled assignment of more resources to urban areas earlier, allowing for saving 25 houses.
Concentrate on protection of life and property instead of perimeter control	Basic decision would not have changed. Accurate information on current fire position might have reduced suppression costs by 10 percent.
Establish secondary lines at Harbison Canyon and Suncrest	Credible perimeter prediction might have obtained more resources for the Suncrest area allowing for saving 25 houses (same houses as above).

e. Calculation of FIRESCOPE Savings

Improved regional resource inventory control would have allowed additional engines to be assigned to the Suncrest area, enabling a savings of 25 houses. Real-time infrared photos of the fire would have provided for improved situation assessment, reducing suppression costs by 10 percent.

If the assumptions are made that it would have taken 15 hours to establish a secondary line at Japatul Road and that the line would have been undertaken if a computerized prediction had indicated sufficient time to build the line, it is possible to assess the impact of a formal fire prediction model. Using 8:00 am on the first day of the fire as a point of reference, it took 18 hours for the fire to reach Japatul Road. Under an $\alpha = 1/2$ computerized prediction, the predicted time of arrival would have been normally distributed, with mean 18 hours and standard deviation 4.5 hours. The probability of the predicted arrival time being less than 15 hours would have been:

$$P(\text{predicted arrival time} < 15) = N\left(\frac{18 - 15}{4.5}\right)$$

$$= 0.745$$

If we assume that there was a 1-percent chance of the line holding and we continue the assumption that the line would be attempted if the prediction indicated sufficient time to complete the line, then the expected savings at the Japatul Road for the $\alpha = 1/2$ system are $0.745 \times 0.01 \times 125{,}000 = 930$ acres. Similar calculations give savings of 1,050 and 1,220 acres for $\alpha = 1/3$ and $\alpha = 1/6$, respectively. Proportional savings in suppression costs are also assumed.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Initial perimeter control of Sunrise Highway and I-8	No effect.
Order all available resources for major project fire	Credible perimeter prediction would have emphasized urgency of request and might have enabled assignment of more resources to urban areas earlier, allowing for saving 25 houses.
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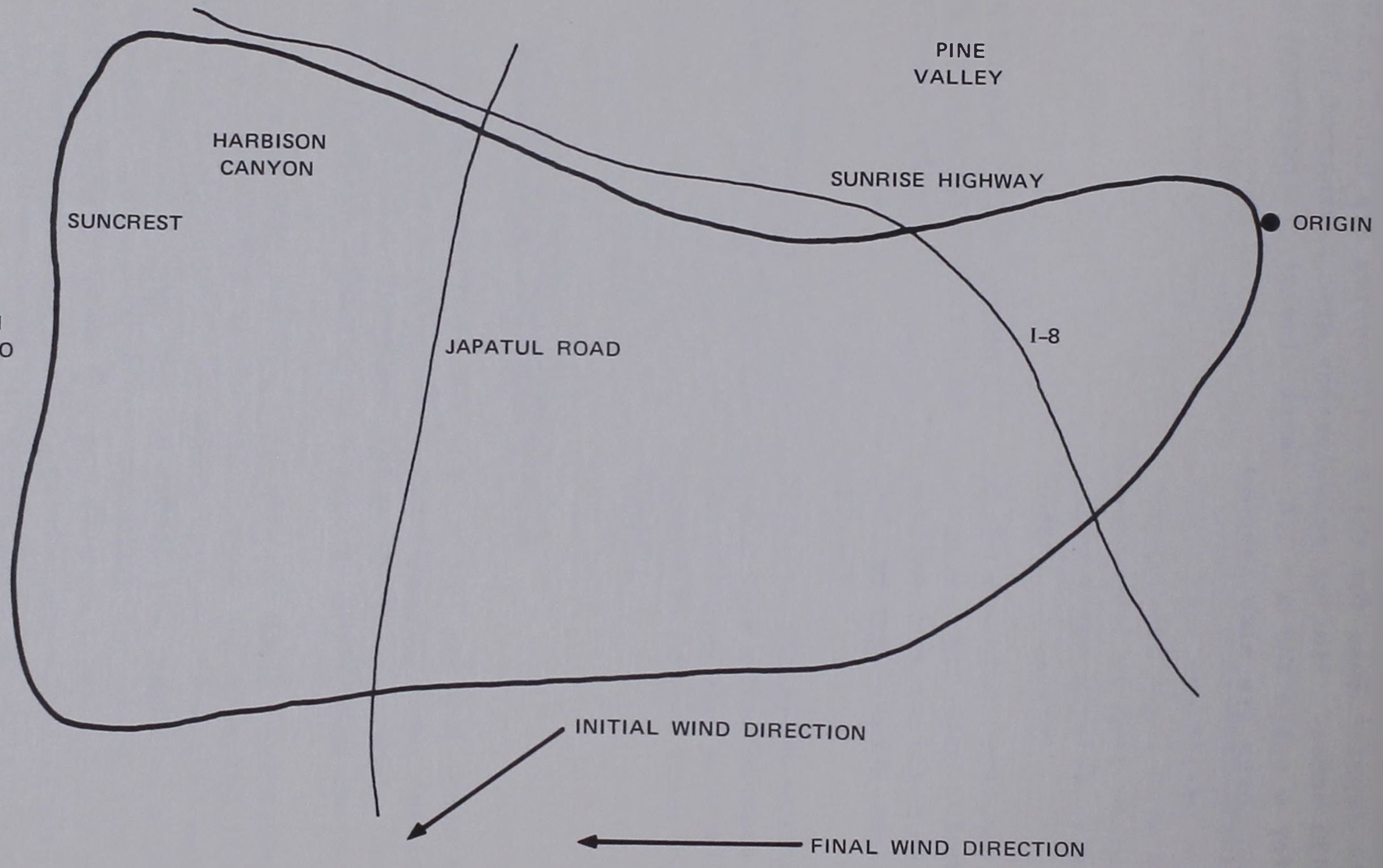

FIGURE A-12 SIMPLIFIED MAP OF LAGUNA FIRE

Table A-13

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON LAGUNA FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	175,420	175,420	175,420	174,490	174,370	174,200	174,170
Houses	382	357	357	357	357	357	357
Damage (dollars)							
Acreage	$33,329,800	$33,329,800	$33,329,800	$33,153,100	$33,130,300	$33,098,000	$33,092,300
Houses	30,712,800	28,702,800	28,702,800	28,702,800	28,702,800	28,702,800	28,702,800
Suppression cost (dollars)	1,500,000	1,500,000	1,350,000	1,343,000	1,342,000	1,339,300	1,339,300
Total cost plus loss (dollars)	$65,542,600	$63,532,600	$63,382,600	$63,198,900	$63,175,100	$63,140,100	$63,134,400

14. Boulder Fire, September 28-October 3, 1970. Based on discussions with Myron Lee (USFS).

a. General Conditions

Weather:	severe fire weather
Fuel:	heavy brush and timber
Terrain:	steep to rolling hills
Acreage burned:	12,900 acres
Houses destroyed:	5
Suppression costs:	$1,500,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$270	Administrative Review
Other ($/acre)	65	SRI
Total	$335	
Structural-related losses:		
$53,600 per destroyed house		Lee/SRI

c. Fire Narrative

The Boulder fire broke out shortly after the Laguna fire made its major run. Nearly all the resources in the region had been committed to the Laguna fire. The Boulder fire had already escaped when the initial attack arrived and it was not until two hours after the fire started that a meeting could be held to organize for another major fire.

The decision was made to divert the two additional zones that were being sent to the Laguna fire over to the Boulder fire. According to Myron Lee, there was great concern about another 100,000 to 200,000 acre fire developing and so the fire was staffed for such an effort. He said that there was little explicit planning on where the fire would go and how big it would get when the initial calls for resources were made.

Lee feels that if an explicit accounting of the winds, fuel, and terrain had been made at the outset, they would have realized how unlikely another 200,000-acre fire would be. They probably could have cut the suppression costs by 30 percent and still have covered all contingencies. Instead they planned for a 200,000-acre fire and ordered the necessary resources for that size effort.

The fire was contained at 12,900 acres. The Forest Service spent $1,100,000 in suppression costs on the fire. That compares with the $1,000,000 that the Forest Service spent on the Laguna fire that burned 175,420 acres.

Although there was measurable slopover on the fire, it is doubtful that the fire could have been contained at significantly fewer acres.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Order resources for major campaign fire	Careful initial assessment of fire conditions would have allowed a 30-percent reduction in suppression costs.

e. Calculation of FIRESCOPE Savings

A careful assessment of wind, fuel, and terrain, as would have occurred under a simple computerized prediction system ($\alpha = 1/2$), would have allowed for suppression cost savings of 30 percent.

Table A-14

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON BOULDER FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards	Common Training, Terminology, Procedures, and Organizational Standards
	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination	Improved Communication and Coordination
	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory	Computerized Resource Inventory
	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:	Perimeter Modeling:
	• Prediction Wheel	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering	• Infrared Telemetering
		• Prediction Wheel	• Computerized Prediction System ($\alpha = 1/2$)	• Computerized Prediction System ($\alpha = 1/3$)	• Computerized Prediction System ($\alpha = 1/6$)	• Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	12,900	12,900	12,900	12,900	12,900	12,900
Houses	5	5	5	5	5	5
Damage (dollars)						
Acreage	$4,321,500	$4,321,500	$4,321,500	$4,321,500	$4,321,500	$4,321,500
Houses	268,000	268,000	268,000	268,000	268,000	268,000
Suppression cost (dollars)	1,500,000	1,500,000	1,500,000	1,050,000	1,050,000	1,050,000
Total cost plus loss (dollars)	$6,089,500	$6,089,500	$6,089,500	$5,639,500	$5,639,500	$5,639,500

15. Stewart Fire, December 14-19, 1958. Based on discussions with Myron Lee (USFS).

a. General Conditions

Weather:	variable winds
Fuel:	mixed grass and brush
Terrain:	rolling hills
Acreage burned:	68,300 acres
Houses destroyed:	14
Suppression costs:	$1,878,000

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$100	Myron Lee/Joe Springer
Other ($/acre)	35	SRI
Total	$135	
Structural-related losses:		
$72,000 per destroyed house		Lee/SRI

c. Fire Narrative

The Stewart fire began on the Stewart Ranch under strong easterly winds. The fire spread toward the ocean and initial efforts were directed toward flanking the fire and pinching it off. It was characteristic of the region and time of the year for the winds to shift in the late afternoon from easterly to westerly. But no secondary effort was established to plan for that contingency, and so when the winds shifted the fire officials were caught completely unprepared. The fire burned back uphill and burned about 20,000 acres above the initial burn path.

Myron Lee said that if even the simplest fire prediction capability had been available, they would have realized the possibility of the wind shift and planned for that contingency. The Ortega Highway would have provided an ideal location for the secondary effort. They could have fired out the section between Verdugo and Lucas Canyons (where the fire was headed) and then they could have begun firing the highway back uphill toward San Juan Station and above.

Myron said the crews were available and the weather conditions were suitable for such a firing effort. All they needed was to realize that the fire might shift direction and the decision would have been made to fire out the lower portion of Ortega Highway. It would not have required a sophisticated system to recognize the contingency. The shift to onshore winds is typical for that area and, indeed, the Kelley fire had burned in the immediate area only weeks before in which the same wind shift had occurred.

Firing out Ortega Highway would have prevented the 20,000-acre uphill loss. It would have also saved the loss of 14 summer homes valued at $15,000 each in 1958 dollars, and many barns and other structures that were lost when the fire burned through San Juan Station. Furthermore, by eliminating the uphill effort, Myron estimated that they probably could have saved an additional 5,000 to 15,000 acres in the area along the road from the Ortega Highway to Indian Potrero. The latter savings would have occurred because they would have had more resources that could have been devoted to the eastern flank of the fire.

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Conduct direct attack and do not fire out Ortega Highway.	A fire prediction system would have shown importance of firing out Ortega Highway and would have allowed saving up to 30,000 acres.

e. Calculated FIRESCOPE Savings

The simplest system that would have freed the incident commander to consider the strategic development of the fire would have allowed him to recognize the threat to the Ortega Highway. Under these circumstances, a strong secondary effort would have been established at the highway, allowing for saving 30,000 acres and for proportional savings in suppression costs. Fourteen houses also would have been saved. The savings will be assigned to Alternative 2, because of its improved organizational structure and situation assessment capabilities.

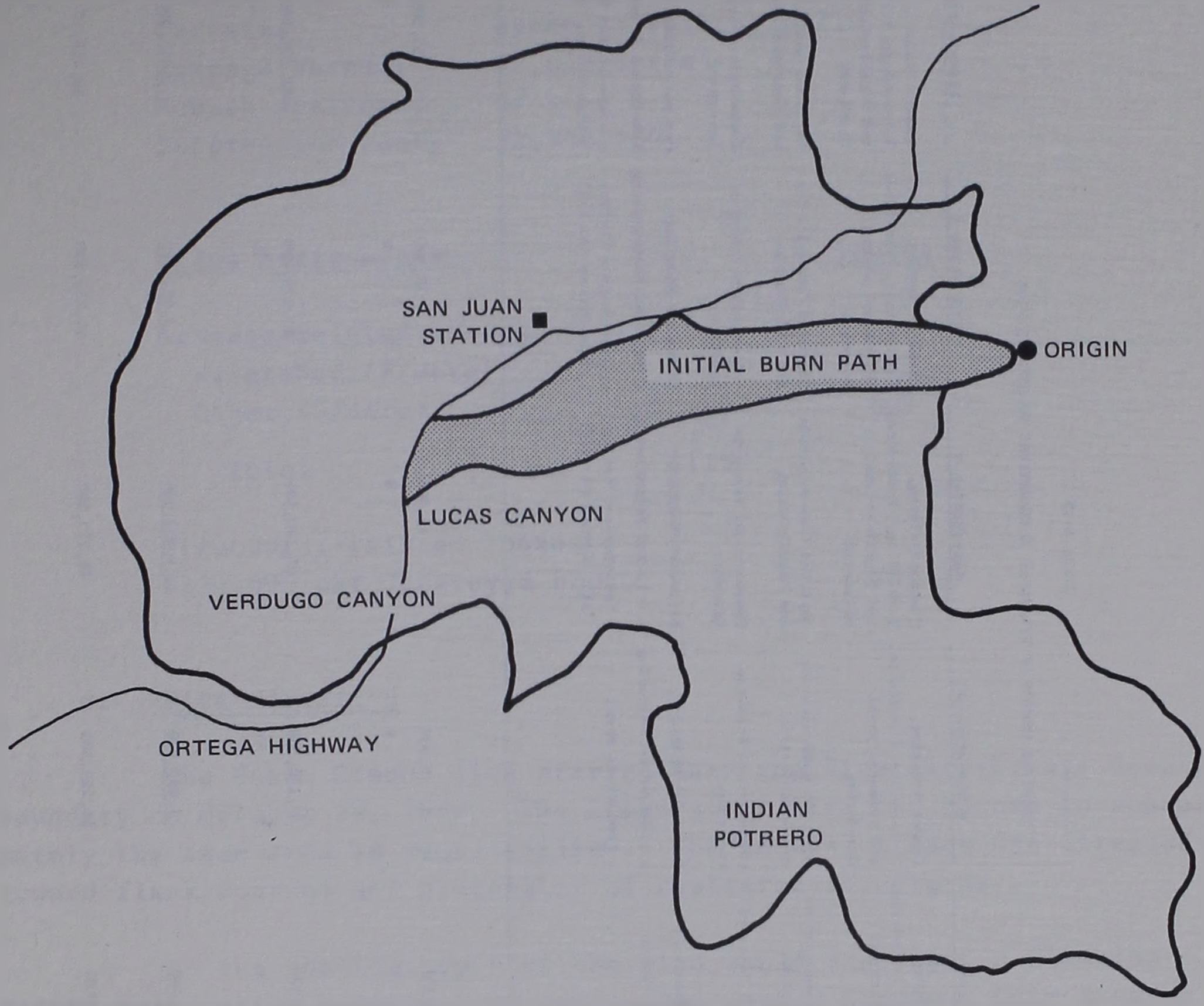

FIGURE A-13 SIMPLIFIED MAP OF STEWART FIRE

Table A-15

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON STEWART FIRE

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses						
Acreage	68,300	38,300	38,300	38,300	38,300	38,300
Houses	14	0	0	0	0	0
Damage (dollars)						
Acreage	$ 9,220,500	$5,170,500	$5,170,500	$5,170,500	$5,170,500	$5,170,500
Houses	1,008,000	--	--	--	--	--
Suppression cost (dollars)	1,878,000	1,053,000	1,053,000	1,053,000	1,053,000	1,053,000
Total cost plus loss (dollars)	$12,106,500	$6,223,500	$6,223,500	$6,223,500	$6,223,500	$6,223,500

16. Paseo Grande Fire, October 29-November 2, 1967. Based on discussions with Carl Downs (CDF).

a. General Conditions

Weather	severe fire weather
Fuel:	20-year-old brush
Terrain:	steep to rolling hills
Acreage burned:	48,639 acres
Houses destroyed:	67
Suppression costs:	$2,944,750

b. Value Assignments

		Source
Acreage-related losses:		
Watershed ($/acre)	$ 50	SRI
Other ($/acre)	65	SRI
Total	$115	
Structural-related losses:		
$134,000 per destroyed house		SRI

c. Fire Narrative

The Paseo Grande fire started near the Riverside-Orange County boundary on October 29, 1967. The Green River fire had burned in approximately the same area 19 years earlier. The initial attack was directed toward flank control and protection of scattered structures.

On the contingency that the wind would die down, a flanking action was started between Coal Canyon and Gypsum Canyon. Only five or six engines were employed and the line was lost because the wind never died down. If a prediction had been given less than a 20-percent chance of success, the action would have been canceled.

The fire began spotting at 1:00 am and a number of communities including Lemon Heights, Cowan Heights, Orange Park Acres, and Villa Park were threatened. However, the fire was very smoky and there was little

information as to where it was headed. Even at 2:00 am it was felt that the fire would not reach Orange Park Acres until 10:00 am. It was believed that the other communities were not as significantly threatened. Carl Downs maintains that if they had had real-time infrared information on the fire and a prediction on when it was going to arrive in the residential areas, then 70 percent of the structural losses could have been eliminated because they would have ordered and used the equipment more effectively. They would have been able to achieve those savings even if the predicted arrival had been for 6:00 am instead of 4:00 am as actually occurred. The infrared photos would have accounted for one-third of the savings, and the other two-thirds would have come from perimeter prediction. No acreage savings would have occurred.

The decision to backfire Santiago Canyon Road was made at 8:00 am. The Santiago Canyon backfiring was a "last ditch" effort and was started at 11:00 am. Under ideal conditions it would have taken two hours to backfire that line. Within 15 minutes of its start, however, the backfire was lost. Earlier backfiring would not have been attempted as a strong wind prevailed. Success would have saved many man-hours of effort and 8,000 acres of medium watershed value.

Keeping track of equipment was a problem, especially for those that did not have the same radio frequency. One piece of equipment was lost for 14 to 20 hours. The safety of personnel could have been significantly improved through better communication. With the same resources, better communication and coordination could have reduced 35 to 40 percent of the structural losses.

An important observation is to be noted here concerning the interdependence of the various FIRESCOPE functions. For example, in this fire, just better communication would have saved 40 percent of the structural loss. With early warning, more equipment and poor communication, the reduction would have been about 60 percent. However, with good communication, early warning, and more equipment, the reduction could have been as much as 80 percent.

FIRESCOPE by providing improved coordination, communication, resource inventory, and fire prediction could have reduced up to 80 percent of the structural losses. It would have increased the suppression costs slightly. The effects of these functions are summarized below.

	Reduction Due To				
	Communication and Coordination	Infra-red	Perimeter Prediction	Resource Inventory	Total System
Acreage saved	0	0	0	0	0
Structures saved	20-22	12-15	33	10	45

d. Summary of Major Decisions

Decision	Possible Impact of FIRESCOPE
Undertake heavy flanking action around the fire	No significant impact.
Defend truck trail with 5 to 6 units	This decision might have changed but significance is small.
Prepare for 9:00 am fire arrival in urban areas	Infrared pictures and perimeter prediction could have reduced 70 percent of the structural losses.
Backfire at Santiago Canyon Road	No effect.
Evacuate Santiago	No effect.

e. Calculation of FIRESCOPE Savings

Improved resource inventory, and communication and coordination would have enhanced the efficiency of the suppression effort, resulting in saving 20 houses. Real-time infrared photos would have emphasized the threat to the urban areas, allowing for saving 13 additional houses. A simple formalized prediction system ($\alpha = 1/2$) would have indicated the threat to the residential areas, allowing for saving 21 additional houses. A precise prediction was not needed, because even if the prediction on when the fire would reach the communities was two hours in error, the decision would have been made to significantly strengthen and hasten the defensive preparations for the residential areas.

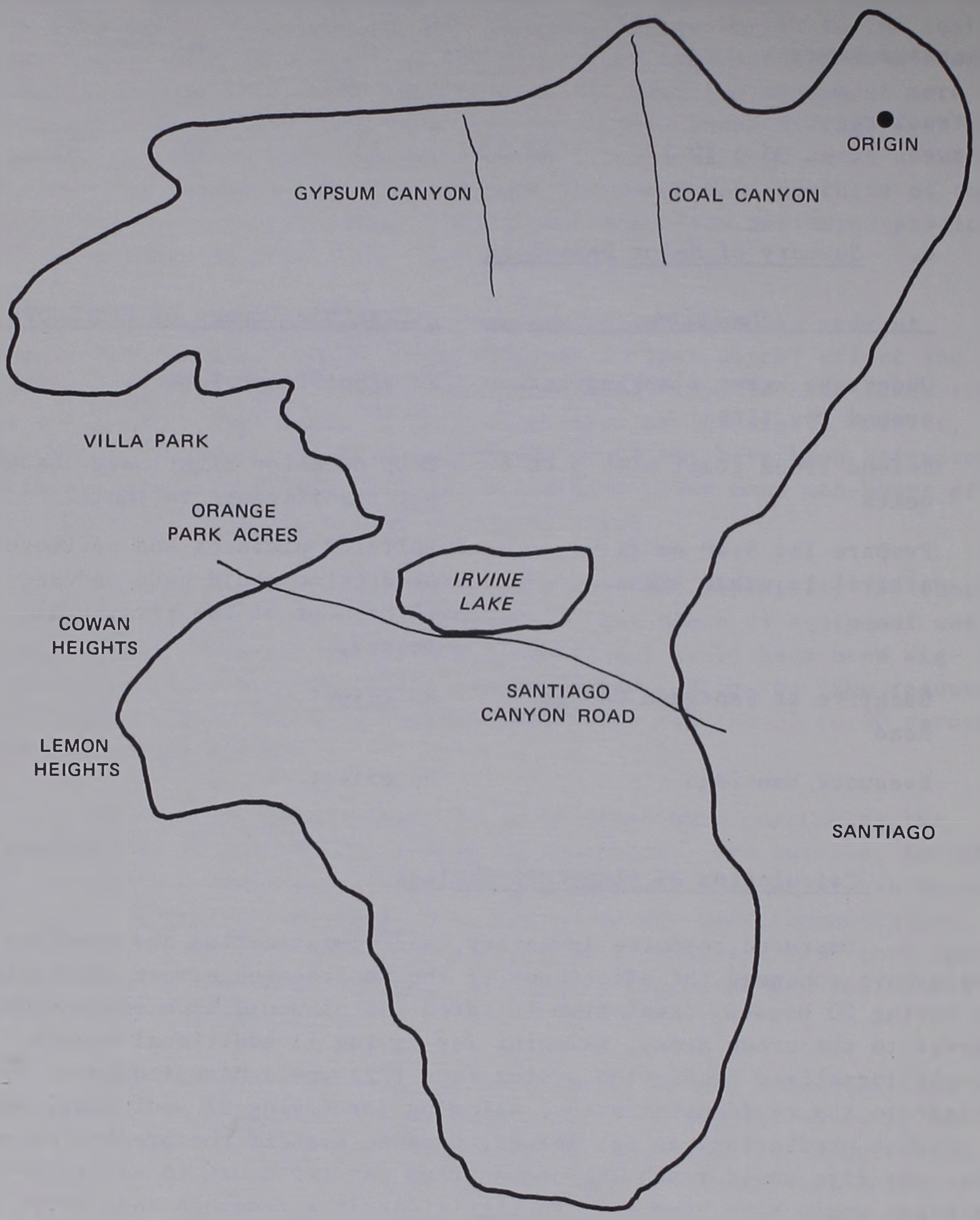

FIGURE A-14 SIMPLIFIED MAP OF PASEO GRANDE FIRE

Table A-16

POSSIBLE EFFECT OF FIRESCOPE ALTERNATIVES ON PASEO GRANDE FIRE

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	Existing Fire Protection System at the time of the fire	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Prediction Wheel	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/2$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/3$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Computerized Prediction System ($\alpha = 1/6$)	Common Training, Terminology, Procedures, and Organizational Standards Improved Communication and Coordination Computerized Resource Inventory Perimeter Modeling: • Infrared Telemetering • Perfect Information on Fire Behavior Conditions after Escape (perhaps not achievable in practice)
Losses							
Acreage	48,639	48,639	48,639	48,639	48,639	48,639	48,639
Houses	67	47	34	13	13	13	13
Damage (dollars)							
Acreage	$ 5,593,485	$ 5,593,485	$ 5,593,485	$ 5,593,485	$ 5,593,485	$ 5,593,485	$ 5,593,485
Houses	8,978,000	6,298,000	4,556,000	1,742,000	1,742,000	1,742,000	1,742,000
Suppression cost (dollars)	2,944,750	2,944,750	2,944,750	2,944,750	2,944,750	$ 2,944,750	$ 2,944,750
Total cost plus loss (dollars)	$17,516,235	$14,836,235	$13,094,235	$10,280,235	$10,280,235	$10,280,235	$10,280,235

Appendix B

DETAILED SENSITIVITY ANALYSIS CALCULATIONS

Appendix B

DETAILED SENSITIVITY ANALYSIS CALCULATIONS

This appendix will summarize the important sensitivity studies that were performed to determine how the results of our analysis would be changed under different assumptions on FIRESCOPE's performance. Results will be given for each of the major scenarios that were offered as an alternative to the ones used in our base case analysis. Results will also be given to help identify possible upper and lower bounds on the maximum potential savings of FIRESCOPE and on the maximum value of a computerized prediction system relative to a manual prediction system.

1. Single Fire Changes

a. Potrero Fire Alternative Scenario

Infrared photos would have been available and the forces would not have been diverted to state park, but there would have been only a 75-percent chance of successfully firing out Big Sycamore Canyon. A successful firing operation would have saved 2,000 acres and an unsuccessful operation would have resulted in the same burn perimeter as occurred. As shown in the following tabulation, this change would have had a minimal effect on the reduction factors for the 16 fires.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.06%	22.77%	22.82%	23.74%	24.80%
Change (percent)	0	0	-0.05	-0.05	-0.05	-0.05	-0.05

b. Romero Fire Alternative Scenario

It would have been impossible to contain the fire at an intermediate ridgetop. Therefore, the expected savings of 3,625 acres and associated suppression costs would not have occurred even if perfect information on fire conditions had been available. As shown in the following tabulation, this change would have had only a marginal effect on Alternative 7.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.56%	23.27%	23.32%	24.24%	24.58%
Change (percent)	0	0	0	0	0	0	-0.72%

c. Coyote Fire Alternative Scenario A

It would have been impossible to mobilize the required additional forces for the reinforcement of the direct attack in the Santa Barbara front country and the secondary efforts at the Camino Cielo and Santa Ynez River. Therefore, there would have been no chance of containing the fire at either 750 acres, 22,000 acres, or 47,000 acres. From the Coyote Fire narrative, given in Appendix A, the effect of this change is calculated as follows:

$$\text{Acreage losses} = (0.1 \times 100) + (0.9 \times 67{,}000)$$
$$= 60{,}310 \text{ acres}$$

$$\text{Housing losses} = (0.1 \times 10) + (0.9 \times 110) = 100 \text{ houses}$$

$$\text{Cost plus loss} = \$44{,}244{,}200$$

The following tabulation shows that this scenario would reduce the total FIRESCOPE savings for the 16 fires by about 10 percent. Thus the assumptions on the Coyote fire are critical to this analysis.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	8.82%	9.76%	13.34%	13.39%	13.41%	14.47%
Change (percent)	0	-9.80	-9.80	-9.93%	-9.93	-10.83%	-10.83%

d. Coyote Fire Alternative Scenario B

Good field communications and an $\alpha = 1/6$ computerized perimeter prediction system would have been necessary to realize the need to reinforce the perimeter control effort of the first night. Resources would not have been available for the Camino Cielo or for the Santa Ynez River efforts. The losses under Alternatives 6 and 7 are calculated as follows:

Acreage = $(0.1 \times 100 + (0.9 \times 0.54 \times 750)$
$+ (0.42 \times 67,000)$
= 28,500 acres

Housing = $(0.1 \times 10) + (0.9 \times 0.54 \times 20)$
$+ (0.42 \times 110)$
= 56.83 houses

Cost plus loss = $22,062,900

The following tabulation shows that our assumption of being able to manually recognize and respond to the communication and coordination problems the first night is critical to the calculated effectiveness of Alternatives 2, 3, 4, and 5.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	8.82%	9.76%	13.34%	13.39%	22.19%	23.25%
Change (percent)	0	-9.8	-9.8	-9.93	-9.93	-2.05	-2.05

e. Coyote Fire Alternative Scenario C

Under an $\alpha = 1/6$ system it would have been possible to save the houses in the Santa Barbara front country and also have a 10-percent chance of containing the fire at the Santa Ynez River. There would have been no chance of containing the fire at 750 or 22,000 acres. The losses under this scenario are calculated as

$$\begin{aligned} \text{Acreage} &= (0.1 \times 100) + (0.9 \times 0.1 \times 47{,}000) \\ &\quad + (0.81 \times 67{,}000) \\ &= 58{,}510 \text{ acres} \end{aligned}$$

$$\begin{aligned} \text{Housing} &= (0.1 \times 10) + [0.9 \times (110 - 45)] \\ &= 59.5 \text{ houses} \end{aligned}$$

$$\text{Cost plus loss} = \$38{,}399{,}955$$

The effect of this scenario is given in the following tabulation and, as above, the scenario shows the extreme sensitivity of our analysis to the assumptions on the Coyote fire.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	8.82%	9.76%	13.34%	13.39%	15.72%	16.78%
Change (percent)	0	-9.80	-9.80	-9.93	-9.93	-8.52	-8.52

f. Soboba Fire Alternative Scenario A

The combination of a resource inventory capability and an α = 1/6 perimeter prediction system would have shown the need for assigning more senior personnel to the fire at the outset. There would have been a 50-percent chance of getting the necessary personnel soon enough and, if they arrived in time, there would have been a 50-percent chance of containing the fire at the Indian Truck Trail, reducing losses to 100 acres valued at $300 per acre. The losses under this scenario would be:

$$\text{Acreage} = (0.5 \times 100 \times 300) + [0.5 \times (\text{losses under } \alpha = 1/6 \text{ system})]$$

$$= 150{,}000 + 1{,}836{,}000 \text{ acres}$$

$$\text{Cost plus loss} = \$1{,}986{,}000$$

As shown in the following tabulation, this scenario would have marginally increased the attractiveness of Alternatives 6 and 7.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.56%	23.27%	23.32%	24.91%	25.97%
Change (percent)	0	0	0	0	0	+0.67	+0.67

g. Soboba Fire Alternative Scenario B

The decision to fire out the Banning-Idylwild Highway would have been made if there had been improved communication and coordination and an improved organizational structure. The expected savings of 5,500 acres and associated suppression costs would have been shifted from the computerized prediction system to the manual system (Alternative 2). As shown in the following tabulation, this change would have given a reasonably small improvement to the calculated benefits of Alternatives 2 and 3.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	20.20%	21.14%	23.27%	23.32%	24.24%	25.30%
Change (percent)	0	+1.58	+1.58	0	0	0	0

h. Soboba Fire Alternative Scenario C

The Banning-Idylwild Highway would not have been fired out under any FIRESCOPE system. The following tabulation shows that this change would have reduced the effectiveness of Alternatives 4, 5, 6, and 7 by about 1.5 percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.56%	21.76%	21.81%	22.73%	23.79%
Change (percent)	0	0	0	-1.51	-1.51	-1.51	-1.51

i. Rolling Hills Fire Alternative Scenario A

Perfect information on fire behavior would have shown the need for a substantially augmented initial attack, allowing for the fire to be contained at less than 100 acres. All the housing losses and most of the acreage losses would have been saved. Because of the small contribution of the Rolling Hills fire to the 16 fires, the following tabulation shows that this change would have had only a small impact on Alternative 7.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.56%	23.27%	23.32%	24.24%	25.86%
Change (percent)	0	0	0	0	0	0	+0.56

j. Rolling Hills Fire Alternative Scenario B

It would have been impossible to initiate the perimeter prediction system in time to have any effect on the housing losses. Therefore, no savings can be attributed to perimeter prediction. The following tabulation shows that this change would not have had a major impact on the 16 fire totals.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.62%	19.56%	22.8 %	22.85%	23.77%	24.8 %
Change (percent)	0	0	0	-0.47	-0.47	-0.47	-0.50

k. Wright Fire Alternative Scenario

The 20-percent savings in acreage would not have occurred under any FIRESCOPE system. The following tabulation shows that this change would have reduced the calculated effectiveness of FIRESCOPE by about one-half percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.04%	18.98%	22.69%	22.74%	23.66%	24.72%
Change (percent)	0	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58

l. Topanga Fire Alternative Scenario

The decision would not have been made to fire out Topanga Canyon Boulevard under any FIRESCOPE system. This would have eliminated the expected savings of 320 acres previously assigned to all alternatives. As shown in the following tabulation, this change would have had a negligible effect on the 16 fire totals.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	18.59%	19.53%	23.24%	23.29%	24.21%	25.27%
Change (percent)	0	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03

m. Laguna Fire Alternative Scenario

Resources could not have been dispatched any sooner to the Suncrest area. Therefore, the savings of 25 houses attributed to the resource inventory function would not have occurred. As shown in the following tabulation, this change would have reduced effectiveness of FIRESCOPE alternatives by 0.8 percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	17.82%	18.76%	22.47%	22.52%	23.44%	24.50%
Change (percent)	0	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8

n. Stewart Fire Alternative Scenario

A computerized perimeter prediction system would have been necessary to detect the threat to Ortega Highway. The expected savings of 30,000 acres and 14 houses would shift from Alternative 2 to Alternative 4. The following tabulation shows that this change would have reduced the calculated effectiveness of alternatives 2 and 3 by 2.3 percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	16.29%	17.23%	23.27%	23.32%	24.24%	25.30%
Change (percent)	0	-2.33	-2.33	0	0	0	0

2. Multiple Fire Changes

a. A Possible Lower Bound on FIRESCOPE Effectiveness

Of the scenarios examined, eight assumed that not all the nominal savings would occur: Potrero, Romero, Coyote A, Soboba C, Rolling Hills B, Wright, Topanga, and Laguna. Combining the eight scenarios as follows, gives a plausible lower bound of the maximum potential savings of FIRESCOPE. The tabulation shows that the maximum potential savings of FIRESCOPE could conceivably be as low as 10.3 percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	5.08%	5.97%	9.90%	9.95%	9.95%	10.26%
Change (percent)	0	-13.54	-13.59	-13.37	-13.37	-14.29	-15.04

b. A Possible Upper Bound on FIRESCOPE Effectiveness

Of the scenarios examined, three attributed more savings to FIRESCOPE than nominally assumed: Soboba A, Soboba B, and Rolling Hills A. Combining these scenarios, as follows, gives one estimate on an upper plausible range for the maximum potential savings of FIRESCOPE. The tabulation shows that under the assumed conditions the maximum potential savings of FIRESCOPE might be as high as 26.0 percent.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	20.2 %	21.14%	23.27%	23.32%	24.91%	26.00%
Change (percent)	0	+1.58	+1.58	0	0	+0.67	+1.03

3. The Marginal Improvement of a Computerized Prediction System over Manual Prediction System

a. A Possible Lower Bound on Advantage of Computerized Perimeter Prediction System Relative to Manual Prediction System

The Soboba B scenario shifted savings nominally assigned to a computerized prediction capability to a manual system. The Rolling Hills B scenario eliminates the savings previously attributed to a computerized prediction system relative to a manual one. Compared to the nominal advantage of 3.7 percentage points of Alternative 4 over Alternative 3, this scenario reduces the advantage to 0.9 percentage points.

	FIRESCOPE ALTERNATIVE						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	20.20%	21.14%	22.8 %	22.85%	23.77%	24.8 %
Change (percent)	0	+1.58	+1.58	-0.47	-0.47	-0.47	-0.50

b. A Possible Upper Bound on Advantage of Computerized Perimeter Prediction System Relative to Manual Prediction System

The Coyote B and Stewart scenarios shifted the nominal savings due to perimeter prediction from a manual system to a computerized system. In addition, the Soboba A scenario assumed savings due to a perimeter prediction that were not otherwise assumed. Combining these three scenarios as follows, gives one estimate on the maximum advantage of a computerized prediction system relative to a manual prediction system. Whereas the advantage of Alternative 4 over Alternative 3 was 3.7 percentage points in our nominal case, this scenario makes that difference 5.9 percentage points.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Revised reduction factors for 16 fires (percent)	0	6.49%	7.43%	13.34%	13.39%	22.86%	23.92%
Change (percent)	0	-12.13	-12.13	-9.93	-9.93	-1.38	-1.38

4. Possible Adjustment for Technological Improvements that Have Already Occurred Since the Time of the Fire

Our nominal analysis attributed a significant portion of the possible FIRESCOPE savings to improved communication and coordination and organizational procedures. Several of the fires analyzed occurred a number of years ago, and since then numerous improvements have been made in the way wildland fires are fought. Therefore, there is some question as to whether all the savings nominally attributed to Alternative 2 should in fact be attributed to FIRESCOPE.

In an attempt to identify the fraction of Alternative 2 savings that would occur today because of existing technology improvements and not necessarily because of FIRESCOPE, we will set the Alternative 1 losses for the pre-1970 fires (Coyote, Wellman, Stewart, and Paseo Grande) equal to their Alternative 2 losses. The assumption is that any communication and coordination problem that occurred in 1970 and after could only be eliminated by the presence of FIRESCOPE; but that current (1975) technology would have been sufficient to solve the communication and coordination problems of the pre-1970 fires. Under this assumption the total cost plus loss for the 16 fires is found to be $214 million, and the reductions attributable to the various FIRESCOPE alternatives are as shown in the following tabulation.

	FIRESCOPE Alternative						
	1	2	3	4	5	6	7
Reduction factors for 15 fires (percent)	0	4.06%	5.17%	9.55%	9.59%	10.69%	11.95%
Change (percent)	0	-14.56	-14.39	-13.77	-13.73	-13.55	-13.35

The tabulation gives a much different assessment of the possible FIRESCOPE benefits than given in our nominal assessment (Table 5). The maximum potential savings attributable to FIRESCOPE have been reduced from 25.3 to 12.0 percent. The savings of Alternative 2 have been reduced from 18.6 to 4.1 percent. Thus, if it is found that the costs of acquiring FIRESCOPE are reasonably close to the nominally assessed savings, additional efforts should be expended to accurately ascertain the portion of nominal savings that are attributable to FIRESCOPE and not to existing technology improvements.

In spite of the change in the absolute amount of the total savings, Table 5 shows that the marginal improvement of going from a manual prediction system to relatively crude computerized system (α = 1/2) is still about 4 percentage points.

5. Uniform Changes in All Reduction Factors

Figure B-1 is presented to show how the results of the analysis would change if the assessed reduction factors were in error by a constant amount. The figure gives the present value of the savings for FIRESCOPE alternatives 2, 4, and 7 over a 15-year period at a 10-percent discount rate for different values of the assessed reduction factors. The changes in the reduction factors are given additively in terms of percentage points. Thus, for example, if the correct reduction factor for Alternative 2 is 2 percentage points less than nominally assessed, the present value of the savings under Alternative 2 would drop from $60 million to about $50 million.

6. Uniform Changes in Acreage- and Housing-Related Value Assignments

Figures B-2 and B-3 give the sensitivity of the total cost plus loss for the 16 fires to changes in the acreage- and housing-related value assignments. Figure B-2 shows how the cost plus loss for the 16 fires under selected FIRESCOPE alternatives would change with changes in the acreage-related value assignments given by the incident commanders. The same information is given in Figure B-3 for changes in the housing-related value assignments. Whereas the total cost plus loss of the fires is dependent on the value assignments, the figures show that the relative comparison of alternatives is insensitive to changes in the value assignments.

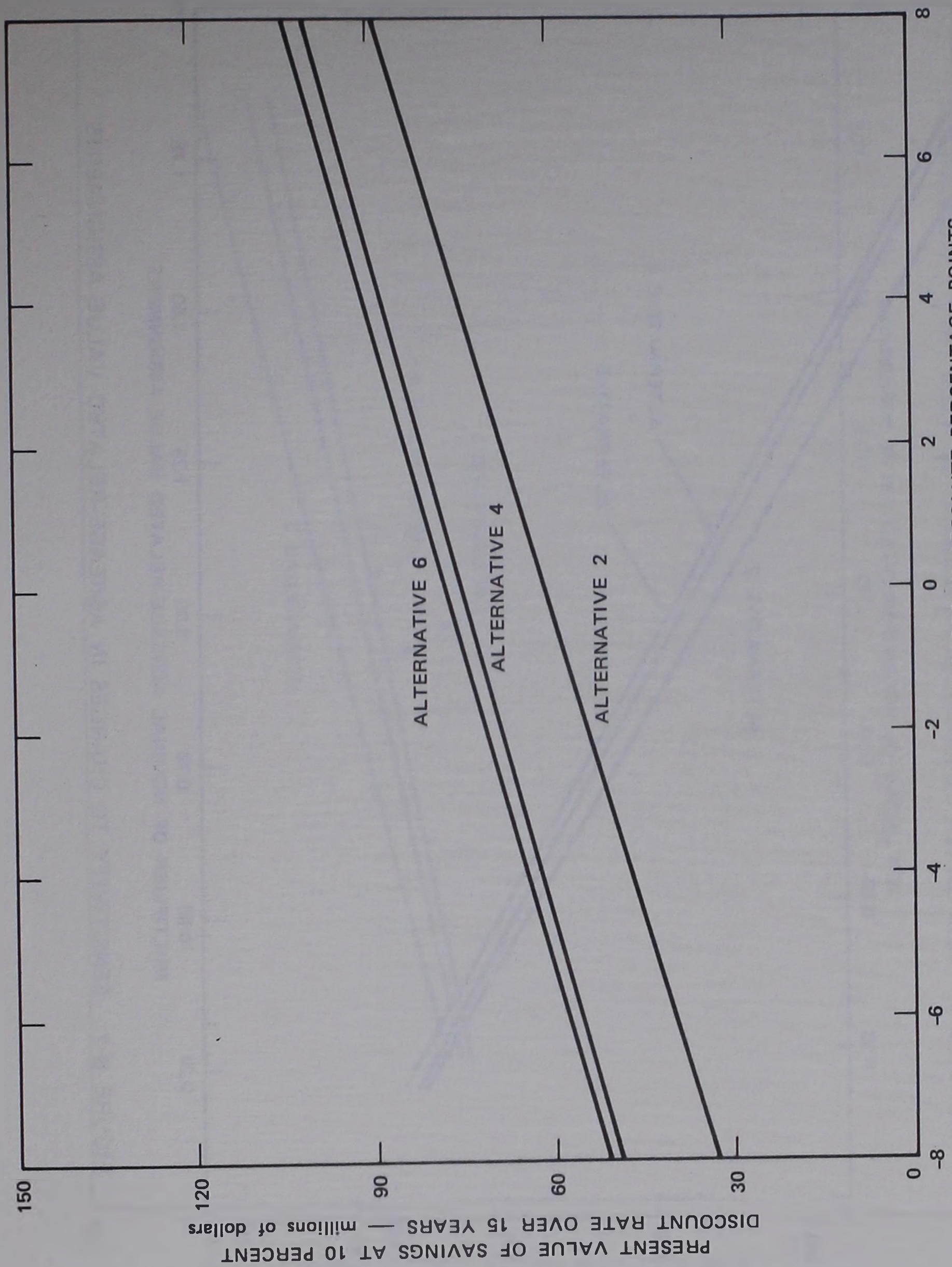

FIGURE B-1 SENSITIVITY TO ADDITIVE CHANGES IN REDUCTION FACTORS

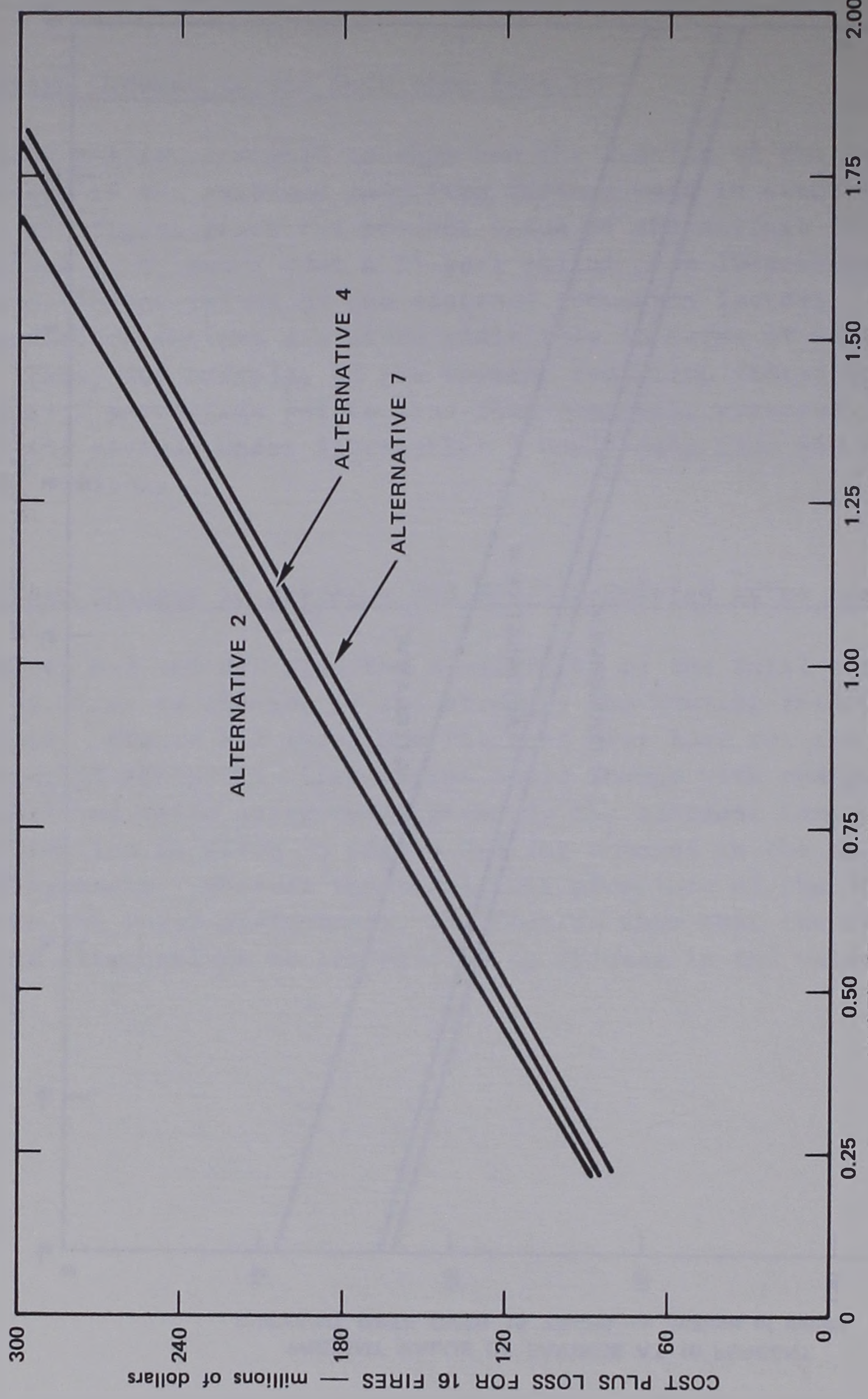

FIGURE B-2 SENSITIVITY TO CHANGES IN ACREAGE-RELATED VALUE ASSIGNMENTS

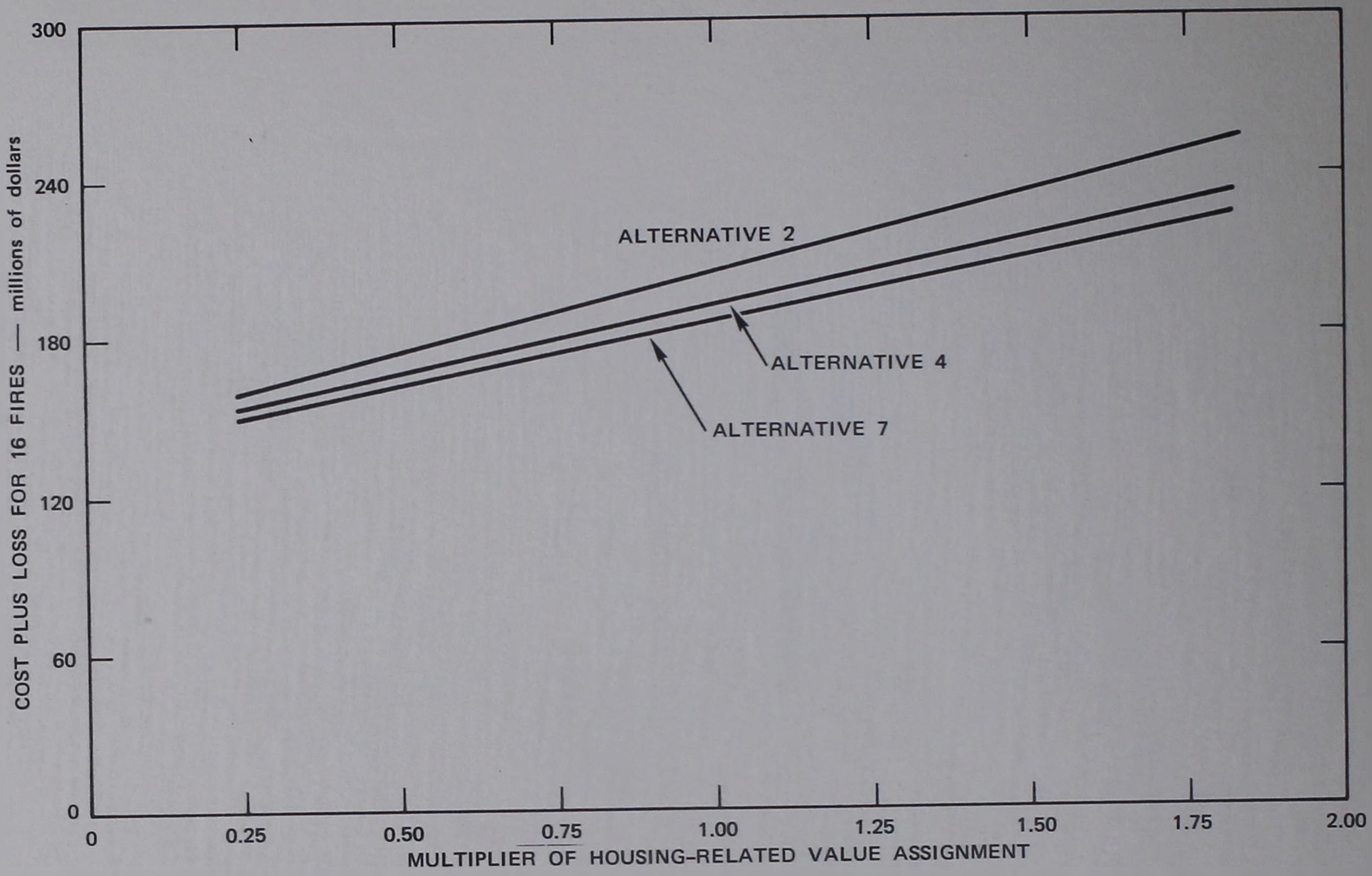

FIGURE B-3 SENSITIVITY TO CHANGES IN HOUSING-RELATED VALUE ASSIGNMENTS

Appendix C

SURVEY DATA FOR 55 FIRES

Appendix C

SURVEY DATA FOR 55 FIRES

This appendix summarizes the potential FIRESCOPE savings that might have occurred on 55 selected fires. The savings were identified during our broad survey of 86 fires and are for the fires where it was judged that FIRESCOPE would have had an effect. The cost-plus-loss figures are based on the value classification scheme developed in SRI's first FIRESCOPE project and summarized in Table 14 of the main report. All values are given in 1970 dollars.

Table C-1

ESTIMATED FIRESCOPE SAVINGS ON 55 FIRES

Fire	SRI Classification	Acres Burned	Dwellings Lost	Suppression Cost (1970 dollars)	Actual Cost Plus Loss (1970 dollars)	Incident Commander's Estimated Percentage Savings Under FIRESCOPE: Acreage Saved (percent)	Dwellings Saved (percent)	Suppression Costs Saved (percent)	Estimated Mininum Cost Plus Loss Under FIRESCOPE (1970 dollars)
Cleveland National Forest									
Morrell (1950)	D	4,970	1	$ 298,200	$ 1,997,750	0%	0%	20%	$ 1,938,110
Conejos (1950)	D	63,700	23	3,822,200	26,969,500	0	0	15	26,396,200
Aqua Tibia (1950)	A*	2,142	0	96,390	224,910	95	--	90	16,065
Banner (1950)	D	1,973	0	118,380	739,875	0	--	20	716,200
Jameson (1954)	D	6,953	0	417,180	2,607,375	0	--	20	2,523,940
Pine Mountain (1956)	A*	6,870	1	309,150	744,950	10	0	30	640,985
Cornwell (1956)	A*	2,970	0	133,650	311,850	0	--	20	285,120
Inaja (1956)	D	43,904	3	2,634,240	16,866,000	10	0	35	14,561,170
Pederson (1957)	D	1,850	0	111,000	693,750	0	--	20	671,550
Chocolate (1957)	D	3,796	0	227,760	1,423,500	15	--	10	1,221,490
Pala (1958)	A	1,680	0	75,600	176,400	0	--	40	146,160
Stewart (1958)	D	68,300	14	4,098,000	27,488,500	30	100	30	17,928,750
Decker (1959)	D	1,405	0	84,300	526,875	0	--	10	518,445
Pleasants (1960)	A*	2,010	2	90,450	318,250	95	100	95	10,550
Outside (1961)	A	2,746	0	123,570	288,330	0	--	20	253,380
Vail (1968)	B	1,498	0	47,900	501,830	0	--	50	464,380
Pechanga (1968)	B	1,776	2	88,800	782,560	10	0	25	709,630
Magee (1968)	A	1,951	0	87,795	204,855	0	--	15	191,685
San Mateo (1969)	A	16,840	0	757,800	1,768,200	50	--	30	1,035,660
Laguna (1970)	D*	175,420	382	10,525,200	116,970,500	0	0	10	116,970,500
Boulder (1970)	D*	12,900	5	774,000	5,507,500	5	0	30	5,072,125
Los Padres National Forest									
White Mountain (1960)	B	12,210	0	610,500	4,090,350	99	--	99	9,525
Coyote (1964)	D	67,000	110	4,020,000	39,865,000	40	15	30	27,939,000
Wellman (1966)	A	93,600	0	4,212,000	9,828,000	12.5	--	10	8,704,800
Schoolhouse (1966)	A	3,375	0	151,875	354,375	0	--	30	308,775
Timber Canyon (1967)	D*	11,448	0	686,880	4,293,000	50	--	75	1,974,780
Poplar (1970)	B	1,260	0	63,000	422,100	0	--	5	418,950
Buckeye (1970)	D*	44,000	15	2,640,000	18,510,000	25	30	25	13,715,000

Table C-1 (Concluded)

Fire	SRI Classification	Acres Burned	Dwellings Lost	Suppression Cost (1970 dollars)	Actual Cost Plus Loss (1970 dollars)	Incident Commander's Estimated Percentage Savings Under FIRESCOPE: Acreage Saved (percent)	Dwellings Saved (percent)	Suppression Costs Saves (percent)	Estimated Minimum Cost Plus Loss Under FIRESCOPE (1970 dollars)
San Bernardino Forest									
McKinley (1956)	D	10,210	5	$ 612,600	$ 4,498,750	50%	100%	50%	$ 1,914,375
Stable (1959)	D	12,822	1	769,320	4,942,250	80	0	60	1,259,390
McKinley (1960)	D*	1,596	0	95,760	598,500	50	--	30	318,400
Sayles (1960)	C	6,620	0	331,000	926,800	25	--	15	728,200
Brook (1962)	D	1,900	0	114,000	712,500	15	--	5	617,025
Cozy Dell (1964)	D	18,265	3	1,095,900	7,251,375	25	100	15	5,246,700
Meyers (1970)	D*	33,920	10	2,035,200	14,060,000	50	100	25	6,868,800
Bear (1970)	D*	53,100	10	3,186,000	21,252,500	5	75	15	19,206,600
Los Angeles County									
Twin Lakes (1954)	B	1,775	2	88,750	782,225	10	0	10	722,620
Latuna (1955)	D*	4,306	0	258,360	1,614,750	30	--	30	1,130,260
Sherwood (1956)	C*	9,428	8	471,400	1,963,120	15	50	15	1,443,550
Newton (1956)	C*	26,170	50	1,308,500	7,683,400	20	50	20	4,941,040
Hume (1956)	D*	1,940	9	116,400	1,933,500	15	0	15	1,824,375
Haskett (1958)	C	4,070	10	203,500	1,373,800	10	30	10	1,075,620
Liberty (1958)	D	17,860	25	1,071,600	10,047,500	10	15	10	8,841,750
Mulholland (1958)	D	4,982	74	298,920	11,784,250	25	75	25	3,880,190
Bel Air (1961)	D*	6,090	484	365,400	67,139,750	30	80	30	14,596,625
Topanga (1961)	D*	8,715	4	522,900	3,804,125	30	25	30	2,689,525
Golden (1962)	A*	9,109	1	409,905	1,010,045	90	0	90	149,250
Onandarka (1962)	D*	8,788	50	527,280	9,995,500	90	95	90	597,615
Weldon (1964)	A*	3,050	0	137,250	320,250	10	--	10	283,905
Wright (1970)	D*	27,925	103	1,675,500	24,273,875	20	30	20	18,025,500
Clampitt (1970)	D*	107,163	86	6,429,780	51,710,125	20	40	20	39,116,775
Ventura County									
Parker Ranch (1967)	D*	25,000	0	1,500,000	9,375,000	95	--	95	468,750
Ditch Road (1967)	D*	1,120	1	67,200	554,000	95	100	95	21,000
Ventura City Foothill (1970)	D*	5,241	3	314,460	2,367,375	25	0	25	1,876,100
Guiberson	D*	12,381	0	742,860	4,642,875	50	--	0	2,321,280

Appendix D

EXPECTED ANNUAL COST PLUS LOSS DUE TO WILDFIRE IN SOUTHERN CALIFORNIA

Appendix D

EXPECTED ANNUAL COST PLUS LOSS DUE TO WILDFIRE IN SOUTHERN CALIFORNIA

This appendix updates the annual cost-plus-loss calculations for Southern California that were made in SRI's first FIRESCOPE project. As before, the calculations are based on the 237 fires of over 1,000 acres each that burned during the period 1950-1970.* The 1,000-acre criterion was selected because most of the cost plus loss in Southern California is due to major fires of over 1,000 acres each.

A number of changes in the losses reported for the 237 fires have been noted since SRI carried out its first FIRESCOPE project. The important changes are listed in Table D-1. The effect of these changes is to change the average annual cost plus loss for the period 1950-1970 from $43.8 million per year to $43.4 million per year. All dollar amounts are expressed in 1970 dollars.

To place the average cost plus loss in perspective, Table D-2 gives the annual cost plus loss by year, from 1950 to 1970. Whereas the average cost plus loss was $43.4 million per year, the table shows that the cost plus loss varied from $1.1 million in 1965 to $282.8 million in 1970. The standard deviation of the 21-year sample was $60.2 million.

Table D-2 also gives the acreage and housing losses by value category (using the value scheme developed in SRI's first FIRESCOPE project and summarized in Table D-3). Sixty percent of the acreage losses and 93 percent of the housing losses occur in Category D, the category of high watershed value and high urban exposures. Thus, if the FIRESCOPE system is built in stages, it would appear that the initial efforts should be directed toward the wildland/urbanized areas of high watershed value.

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*For a list of the fires, see D. W. North, F. L. Offensend, C. N. Smart, "An Economic Evaluation of Multi-Agency Communication and Coordination Systems for Southern California: A Preliminary Assessment," Stanford Research Institute, Menlo Park, California (February 1974).

Table D-1

CHANGES IN LOSSES RECORDED ON SEVEN FIRES

Fire	Jurisdiction	Change
Newhall (Onandarka) (1962)	Angeles/LA County	50 dwellings lost instead of 13
Conejos (1950)	Cleveland	63,700 acres and 23 houses burned instead of 37,520 acres and 5 houses
Chocolate (1957)	Cleveland	3,796 acres burned instead of 2,780
Stewart (1958)	Cleveland	68,300 acres and 14 dwellings burned instead of 66,300 acres and 5 houses
Pechanga (1968)	Cleveland	1,776 acres burned instead of 1,176
Bear (1970)	San Bernardino	10 equivalent dwellings lost instead of none
Wellman (1966)	Los Padres	Change value classification from B to A

Table D-2

HISTORICAL DATA ON ANNUAL COST PLUS LOSS

Year	Acres Burned Fire Classification A	B	C	D	Houses Lost SRI Classification A	B	C	D	Total Cost Plus Loss (dollars)
1950	74,195	13,820	--	76,273	1	--	--	24	$ 44,292,150
1951	31,585	19,920	--	12,440	1	--	--	1	14,842,225
1952	6,197	3,233	--	4,760	--	--	--	--	3,518,740
1953	111,301	40,414	--	28,848	7	1	--	2	36,780,295
1954	8,130	18,786	--	15,886	--	2	--	2	13,559,810
1955	--	1,155	--	121,251	--	--	--	20	48,536,050
1956	14,305	9,147	35,598	75,844	--	--	58	20	45,388,290
1957	26,850	41,226	--	8,316	1	3	--	4	20,619,460
1958	15,767	5,161	21,070	108,764	4	--	10	141	67,033,170
1959	19,047	--	2,250	28,272	--	--	--	3	13,318,935
1960	6,020	28,595	6,620	21,532	2	7	--	31	35,380,525
1961	2,746	7,200	6,300	27,562	--	--	--	502	81,186,080
1962	18,926	5,850	--	35,821	3	--	--	55	24,910,655
1963	1,360	--	--	2,615	--	--	--	--	1,123,425
1964	4,790	--	13,710	97,534	--	--	6	115	54,890,000
1965	1,103	1,527	--	1,260	--	--	--	--	1,099,860
1966	102,515	--	--	2,028	--	--	--	--	11,524,575
1967	13,169	--	24,229	161,583	--	--	15	110	81,314,430
1968	57,985	25,412	--	21,944	--	3	--	2	23,379,845
1969	19,750	5,390	--	6,274	--	--	--	--	6,232,150
1970	17,838	9,159	7,286	501,407	--	--	1	662	282,777,320
Total	553,579	235,995	117,063	1,390,214	19	16	90	1,694	$911,707,990

Note: See Table D-3 for summary of classification scheme.

Table D-3

SUMMARY OF FIRE CLASSIFICATION SCHEME

Structural Exposure	Value of Watershed	Fire Classification
Low	Low	A
Low	High	B
High	Low	C
High	High	D

The frequency data on annual cost plus loss seems to fit a log normal distribution with parameters:

$$\mu = 3.07$$

$$\sigma = 1.39 \quad .$$

The calculated cumulative for the log normal is given in Figure D-1. The graph may be used as an approximating device to calculate the probability of the natural logarithm of the cost plus loss in a particular year falling in a specified range. The logarithms can then be converted to real numbers to give the probability of the annual cost plus loss falling in a particular range.

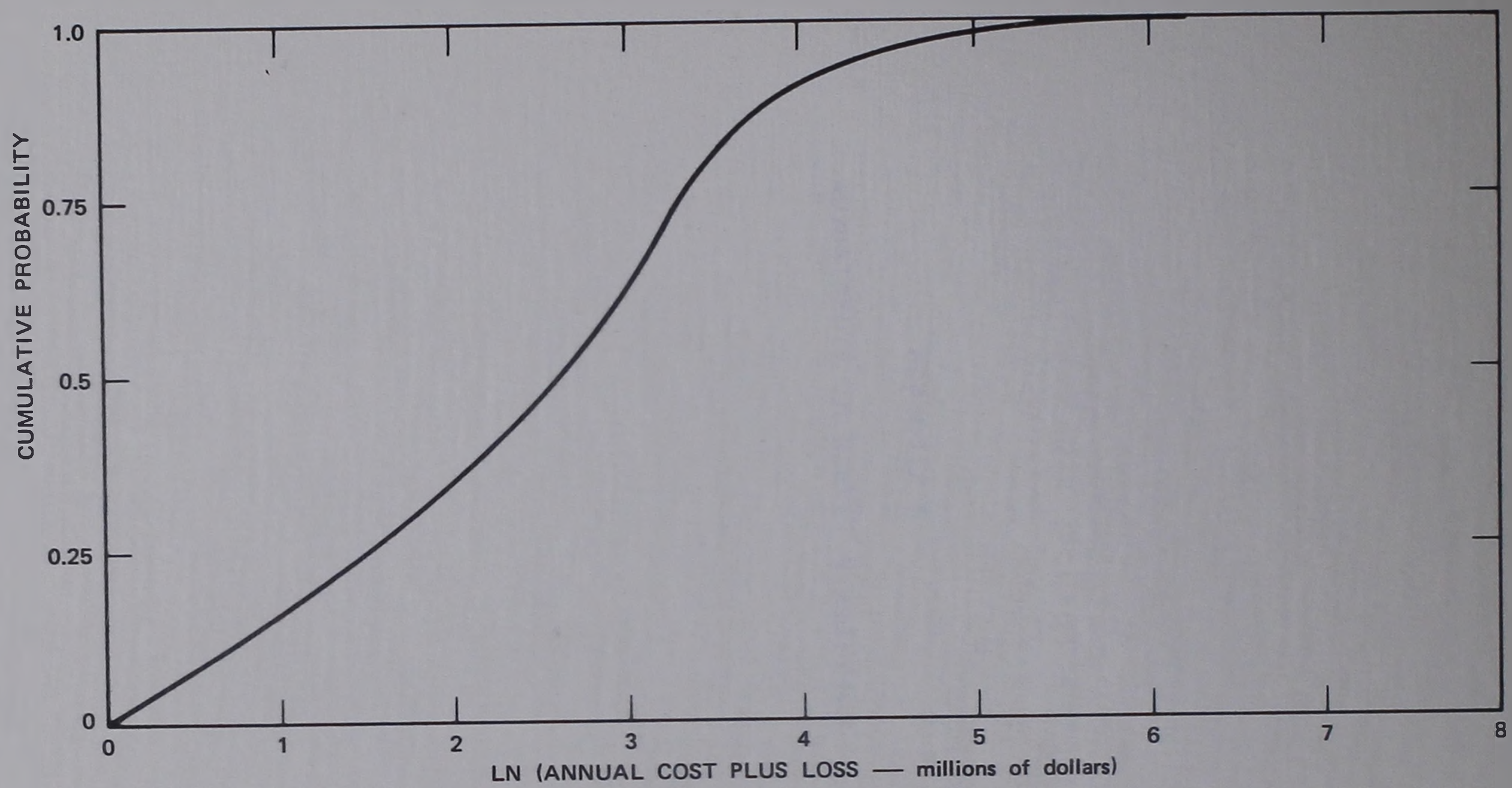

FIGURE D-1 CUMULATIVE LOG-NORMAL DISTRIBUTION FOR COST PLUS LOSS IN A GIVEN YEAR

Appendix E

ADJUSTMENTS IN SURVEY STATISTICS

Appendix E

ADJUSTMENTS IN SURVEY STATISTICS

The 86-fire survey was undertaken in considerably less detail than the 16-fire survey. A number of discrepancies were observed in the indicated savings for the common fires included in both surveys. Where discrepancies occurred, we felt that the results of the 16-fire survey were more reliable, because that survey was carried out in considerably more detail. This appendix presents a method for adjusting the results of the 86-fire survey to reflect possible omissions due to considering the fires in less detail.

As shown in Table E-1, the adjustments are calculated for each incident commander by comparing the savings that were indicated for the common fires in the two surveys. The adjustments are calculated on the basis of the assessments that were made before the draft version of this report was circulated for review. (A number of data changes were made during the review, but since those changes were suggested by individuals not involved in the 86-fire survey, we have not included the revised data in this adjustment exercise.) In order to compare the savings on a consistent basis, the losses for the 16-fire survey were recalculated using the same value scheme (see Table 14 of main text) that was used in calculating the losses for the 86-fire survey. The sum of the differences of the savings for the common fires is then compared with the total cost plus loss for those fires to give the percentage amount by which the savings rate assessed by the incident commander should be adjusted. The savings rate is defined as the percentage level of savings for the fires in which FIRESCOPE savings would have occurred; it does not include the fires in which no savings would have occurred. The assumption was made that the incident commander made proportional biases in estimating the savings on the other fires of the 86-fire survey that were not included in both surveys. Thus the calculated adjustment factor was used to augment or decrease the savings on all fires in which the incident commander indicated savings would occur.

Table E-2 gives the adjustment in savings rate that was calculated for each fire official involved in the survey. Also given in the table are the revised cost-plus-loss calculations that result from the adjustment exercise. The overall effect of the adjustment is to reduce the maximum potential FIRESCOPE savings for the 86 fires from 28.4 to 27.0 percent.

Table E-1

ADJUSTMENTS TO SAVINGS RATE FOR FIRES
SURVEYED BY JERRY BERRY

Fires Surveyed by Jerry Berry Common to 16-Fire Survey and 86-Fire Survey	Actual Cost Plus Loss	Estimated Savings in 16-Fire Survey	Estimated Savings in 86-Fire Survey	Difference Between Columns 3 and 4
Coyote	$39,865,000	$15,878,750	$11,859,000	$4,019,750
Wellman	9,828,000	1,449,000	1,123,200	325,000
Buckeye	18,510,000	3,750,000	7,533,000	-3,783,000
Total	$68,203,000			+$562,500

Adjustment to savings rate for fires in which FIRESCOPE savings would have occurred $= \frac{\$562,500}{\$68,203,000} = 0.8\%$

Original savings rate for fires in which FIRESCOPE savings would have occurred = 34.9%

Revised savings rate for fires in which FIRESCOPE savings would have occurred = 35.7%

Table E-2

ADJUSTMENTS TO 86-FIRE SURVEY STATISTICS

Fire Official	Actual Cost Plus Loss (millions of dollars)	Initial Estimate of Cost Plus Loss Under FIRESCOPE (millions of dollars)	Adjustment to Savings Rate for Fires in Which FIRESCOPE Savings Would Have Occurred (percent)	Revised Estimate of Cost Plus Loss Under FIRESCOPE (millions of dollars)
Jerry Berry (Los Padres)	$ 77.3	$ 46.4	0.8%	$ 49.7
Myron Lee (Cleveland)	213.1	176.3	5.5	187.3
Gene Kemble (San Bernardino)	59.9	45.4	-4.9	43.5
Ben Matthews (Los Angeles County)	207.9	152.2	-10.5	132.4
Carl Downs (Orange County)	1.7	1.7	0.0	1.7
Donald Ellis (Ventura County)	23.5	11.2	0.0	11.2
Total	$583.4	$417.7		$425.7

Appendix F

SURVEY OF 23 ANGELES NATIONAL FOREST FIRES

Appendix F

SURVEY OF 23 ANGELES NATIONAL FOREST FIRES

After we completed our survey of 86 fires, we had an opportunity to query Richard Montague of the Angeles National Forest on the effect that FIRESCOPE would have had on fires that had burned in that forest. However, he was not present at any of the fires, and so his judgments should be viewed as informed opinion based on information he obtained from other sources. For this reason, we will separate the Angeles fires from the other 86 fires surveyed.

Table F-1 lists the 23 Angeles fires surveyed and the cost plus loss that was actually incurred. Of these fires, Montague judged that FIRESCOPE would have had no effect on seven. However, as shown in Table F-2, those fires accounted for 76 percent of total cost plus loss for all 23 fires (which was considerably more than the 5-percent figure observed in the 86-fire survey). Table F-3 lists the 16 Angeles fires where FIRESCOPE was judged to have some effect. The estimated savings on these fires totals $9.8 million. Thus, FIRESCOPE was estimated by Montague to have reduced the cost plus loss on the 23 fires surveyed by 13.9 percent. The 13.9 percent figure compares with 27.0 percent for the 86 fires surveyed earlier in the project.

Table F-1

SURVEY OF ANGELES NATIONAL FOREST FIRES

Fire	Classification	Acres Burned	Dwellings Lost	Total Cost Plus Loss (dollars)
Reese (1960)	B	1,648	1	$ 645,800
Polecat (1960)	B*	14,737	6	5,499,695
Magic (1960)	D*	27,790	1	10,277,350
Johnstone (1960)	D*	22,146	30	12,103,290
Buchanan (1960)	A*	2,560	0	268,800
Chaparral (1960)	A	1,450	0	152,250
Wilson (1961)	C*	6,300	0	882,000
Islep (1961)	B*	1,050	0	351,750
Bootlegger (1962)	A	2,460	2	365,500
Webb (1962)	D	2,160	1	922,400
Newhall (1962)	D*	8,788	13	4,949,620
Bouquet (1963)	D	2,615	0	954,475
Charlie (1966)	A	1,450	0	2,200,200
Dry (1964)	C	12,270	6	1,436,000
Bouquet (1964)	D	3,200	2	152,250
Tujunga (1966)	D	2,028	1	874,220
Brickyard (1967)	A	5,830	0	612,150
Liebre (1968)	A*	49,189	0	5,164,845
Reservoir (1968)	D*	3,270	0	1,193,550
Canyon (1968)	B	20,200	1	6,860,800
Limerock (1968)	D	2,730	0	996,450
Aqua Dulce (1970)	D*	23,790	29	12,569,350
Fork Fire (1970)	B*	3,479	0	1,165,465
Total cost plus loss of surveyed fires				$70,598,290

Note: For value classifications, see Table 14.

Table F-2

ANGELES NATIONAL FOREST FIRES
THAT WOULD NOT HAVE BEEN AFFECTED BY FIRESCOPE

Fire	Classification	Acres Burned	Dwellings Lost	Total Cost Plus Loss (dollars)
Polecat (1960)	B*	14,737	6	$ 5,499,695
Magic (1960)	D*	27,790	1	10,277,350
Johnstone (1960)	D*	22,146	30	12,103,290
Liebre (1968)	A*	49,189	0	5,164,845
Canyon (1968)	B	20,200	1	6,860,800
Aqua Dulce (1970)	D*	23,790	29	12,569,350
Fork Fire (1970)	B*	3,479	0	1,165,465
Total cost plus loss				$53,640,795

Note: For value classifications, see Table 14.

Appendix G

A TUTORIAL EXERCISE ON THE ADJUSTMENT OF PREDICTED FIRE ARRIVAL TIME

This exercise illustrates the adjustment of an incident commander's initial assessment on fire arrival time, given a prediction on fire spread. Our analysis of the importance of perimeter prediction accuracy focused on the question of how accurate the perimeter prediction used by the incident commander had to be. In practice, the incident commander's prediction will be based on his prior assessment of when the fire will arrive at the point of interest, as well as the prediction provided by the formal prediction system. In this appendix, we will illustrate with a simple example how the incident commander should update his prior assessment to take into account the prediction provided by a prediction system of specified accuracy.

For the purpose of this example, assume that the reliability of the prediction system is as shown in Table G-1. The table shows that for each possible arrival time, the prediction system might give any one of several predictions. Thus, for example, if the actual time of fire arrival is 3 hours, the predicted time of arrival might be "2", "3", or "4" hours with probabilities 0.1, 0.8, and 0.1, respectively. Similar predicted times are given for the other possible times.

Also for the purpose of this example, assume that the incident commander's prior assessment on when the fire will arrive at a particular point of interest is as given in Table G-2.

Now assume that a prediction of "2" hours has been made; the problem is to update the incident commander's initial assessment given this new information. To do this, we must first calculate the probability that he would assign to a prediction of "2" hours being made. Notice that if a prediction of "2" hours is made, the actual arrival time might be 1, 2, or 3 hours. From his prior assessment on the arrival time and from the stated reliability of the system, the incident commander would assign a 20-percent chance of the predicted arrival time being 2 hours.

$$P(\text{prediction} = \text{"2"}) = (0.1 \times 0.1) + (0.2 \times 0.8) + (0.3 \times 0.1)$$

$$= 0.20 \quad .$$

Table F-3

ESTIMATED SAVINGS ON FIRES IN ANGELES NATIONAL FOREST

Fire	Classification	Acres Burned	Dwellings Lost	Reduced Cost Plus Loss Under Actual Cost Plus Loss (dollars)	Reduced Cost Plus Loss Under FIRESCOPE Functions (dollars)
Reese (1960)	B	1,648	1	$ 645,800	$ 127,300
Buchanan (1960)	A*	2,560	0	268,800	10,500
Chaparral (1960)	A	1,450	0	152,250	10,500
Wilson (1961)	C*	6,300	0	882,000	14,000
Islep (1961)	B*	1,050	0	351,750	33,500
Bootlegger (1962)	A	2,460	2	365,500	117,700
Webb (1962)	D	2,160	1	922,400	170,500
Newhall (1962)	D*	8,788	13	4,949,620	3,609,620
Bouquet (1963)	D	2,615	0	954,475	36,500
Dry (1964)	C	12,270	6	2,200,200	1,341,300
Bouquet (1964)	D	3,200	2	1,436,000	852,000
Charlie (1966)	A	1,450	0	152,250	10,500
Tujunga (1966)	D	2,028	1	874,200	170,500
Brickyard (1967)	A	5,830	0	612,150	10,500
Reservoir (1968)	D*	3,270	0	1,193,550	596,800
Limerock (1968)	D	2,730	0	996,450	36,500
Total cost plus loss under FIRESCOPE				$16,957,495	$7,148,220

Note: For value classifications, see Table 14.

Appendix G

A TUTORIAL EXERCISE ON THE ADJUSTMENT OF PREDICTED FIRE ARRIVAL TIME

Table G-1

RELIABILITY OF PREDICTION SYSTEM

Actual Time of Fire Arrival (hours)	Predicted Time of Fire Arrival (hours)	Probability of Prediction Given Actual Arrival Time
1	1/2	0.1
1	1	0.8
1	2	0.1
2	1	0.1
2	2	0.8
2	3	0.1
3	2	0.1
3	3	0.8
3	4	0.1
4	3	0.1
4	4	0.8
4	5	0.1

Table G-2

INCIDENT COMMANDER'S PRIOR ASSESSMENT
ON TIME OF FIRE ARRIVAL

Time of Fire Arrival (hours)	Probability
1	0.1
2	0.2
3	0.3
4	0.4

The likelihood that the arrival time will be 1 hour given that the predicted time was "2" hours is the fraction of the above computation that was conditioned on a 1-hour arrival time:

$$P(\text{actual} = 1 \mid \text{predicted} = \text{"2"}) = \frac{(0.1 \times 0.1)}{0.20}$$

$$= 0.05 \quad .$$

Similarly, the following computations give the updated probabilities that he now assigns to arrival times of 2, 3, and 4 hours:

$$P(\text{actual} = 2 \mid \text{predicted} = \text{"2"}) = \frac{(0.2 \times 0.8)}{0.20}$$

$$= 0.80$$

$$P(\text{actual} = 3 \mid \text{predicted} = \text{"2"}) = \frac{(0.3 \times 0.1)}{0.20}$$

$$= 0.15$$

$$P(\text{actual} = 4 \mid \text{predicted} = \text{"2"}) = \frac{(0.4 \times 0)}{0.20}$$

$$= 0 \quad .$$

Similar computations are made for other predicted arrival times. The result of the computations are given in Table G-3, which gives the adjusted assignment for each possible FIRESCOPE prediction.

Table G-3

ADJUSTED PROBABILITY ASSIGNMENT
FOR GIVEN PREDICTED ARRIVAL TIMES

Predicted Arrival Time (hours)	Actual Arrival Time (hours)	Adjusted Probability Assignment on Actual Arrival Time Given Predicted Time
1/2	1	1.0
1	1	0.8
1	2	0.2
2	1	0.05
2	2	0.80
2	3	0.15
3	2	0.07
3	3	0.80
3	4	0.13
4	3	0.09
4	4	0.91
5	4	1.0